R & B ENTERPRISES

FCC DOCKET NO. 80-284

REPORT & ORDER

ADOPTED, FEBRUARY 25, 1981
RELEASED, MARCH 26, 1981

METHODS OF MEASUREMENT OF COMPUTING DEVICES

APPENDIX A: LIST OF COMMENTATORS
APPENDIX B: REVISION TO PARTS 2 & 15 OF FCC RULES & REGULATIONS
APPENDIX C: MEASUREMENT PROCEDURE 1

DIVISION OF EMC SCIENCE CENTER

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In the Matter of)
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Amendments of Parts 2 and 15 of) Gen. Docket 80-284
the Rules relating to verification)
and methods of measurement of)
computing devices.)

REPORT AND ORDER

Adopted: ; Released:

By the Commission:

1. A Notice of Proposed Rulemaking (NPRM) in this proceeding was adopted by the Commission on June 11, 1980, to formalize the methods of measurement and the procedure for verification of computing devices subject to the technical standards in Subpart J of Part 15 (47 CFR Part 15 Subpart J).

2. For the reasons given below, the Commission is adopting herein a procedure for testing computing devices for compliance with the technical standards in Part 15 Subpart J, and also adopting procedural requirements for verification by manufacturers that their equipments satisfy the computing device regulations.

BACKGROUND OF THIS PROCEEDING

3. The Commission established new technical standards to control the interference to radio and TV reception caused by computers and similar digital electronic equipment. These standards were adopted by the Commission on September 18, 1979 in a First Report and Order (hereinafter First Report) in FCC Docket 20780.[1] The rules were later revised on March 27, 1980 in an Order Granting In Part Reconsideration Of the First Report and Order (hereinafter Reconsideration) which delayed the effective date and made some other changes primarily procedural in nature.[2] In these actions, the Commission explained that a separate proceeding would be initiated to establish methods of testing for compliance with the new standards, even though the procedures contemplated were to follow well known and established methods of testing. To the extent practicable, the procedure

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[1] Released October 11, 1979; 44 FR 59530, October 16, 1979; FCC 79-555.

[2] Released April 9, 1980; 45 FR 24154, April 9, 1980; FCC 80-148.

adopted herein follows long-established methods of measurement.

COMMENTS IN RESPONSE TO NPRM

4. Comments were filed in this proceeding by 21 parties (3 associations, 14 companies, 4 consultants) and reply comments were filed by 8 parties. A list of the commenters is attached as Appendix A. In general, the commenters support the proposal. Atari, NTI, and MITA found the proposed test procedures to be unnecessarily complicated and burdensome. The primary concerns deal with acceptability of open field test sites, allowing for flexibility in the test procedure, measurement instrument detector function and bandwidth, and the line impedance stabilization network (LISN). For the reasons discussed in paragraph 5 below, the matter of test sites and criteria for their suitability is being taken up separately. This aside, the following paragraphs address the points made in the comments and explain the Commission's consideration and disposition of them.

FCC DOCKET 21371

5. A Notice of Proposed Rulemaking in Docket no. 21371 was adopted on August 24, 1977 to amend Part 2 of the Rules to require a description of measurement facilities used in the equipment authorization program and to make other related changes.3/ The focus of this action was on open field test sites and what should be considered as the minimum requirements for the site to yield accurate and repeatable measurements. Not knowing when action in Docket 21371 might be finalized, parallel requirements for open field sites were set forth in the computing device measurement procedure proposed in General Docket 80-284. In their comments on Docket 80-284, Motorola and EIA/CEG recommend that the test site requirements in Dockets 80-284 and 21371 be consolidated. We agree that this is desirable both to avoid duplication and to avoid the possibility of any differences between two sets of requirements. Accordingly, comments filed in General Docket 80-284 which relate to open field test sites and their acceptability are being considered in Docket 21371, which we expect to finalize shortly. Comments filed concerning issues peculiar to test sites used for measuring computing devices are taken up herein.

VERIFICATION

6. The regulations adopted in Docket 20780 made most equipments subject to verification. Specifically, Section 15.814 requires verification of Class A computing devices. Section 15.834(b) and (c) require that Class B devices not singled out

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3/ Released June 20, 1980; 42 FR 45342, June 24, 1980; FCC 80-335.

for certification be verified for compliance. A definition of verification was adopted and set forth in Section 15.4(r). Verification is, in essence, a self-certification procedure whereby it is incumbent on the manufacturer to make certain that his device conforms to the standards by performing tests. For other forms of equipment authorization, such as, certification, type approval, and type acceptance, detailed authorization procedures are set forth in the Rules in Subpart J of Part 2. It became apparent from the informal questions received by the Commission following the adoption of the computing device rules that similar statements were necessary to clarify what the Commission expected to be done for equipment subject to verification.

7. Only minor exceptions were taken to the proposed rules concerning verification that are to be added to Part 2. NTI and TI request that Section 2.955, concerning retention of records, be revised to narrow its scope. This requirement calls for the manufacturer to retain a complete set of design drawings for the product and also to keep a record of the procedures used for production inspection and the procedures used for testing for compliance with FCC requirements. It is our belief that retention of the design drawings is a practice which already routinely exists and that this should pose no difficulty. Retention of records on the production inspection and test procedures is the minimum information that would be needed should an interference or other problem arise. TI expressed concern that Section 2.953 might imply that some form of statistical production line emission testing is required. Section 2.953(a)(2) is amended to make it clear that this is not required.

8. Drake Willock and TI commented that Section 2.957 should be revised to say that the costs of shipment of sample devices to the Commission will be borne by the FCC. We do not agree with this and find that the proposal is not in keeping with existing requirements elsewhere in Part 2 (e.g., Section 2.937). CBEMA recommends minor revisions in the language of Sections 2.953 and 2.955 to reflect what is implied in Section 2.902--that in some instances testing may not be warranted. We have incorporated these suggestions. The definition of verification in Section 15.4(r) is deleted since a description of what verification entails is given in the new Section 2.952. The rules concerning verification are otherwise adopted as proposed and can be found in the attached Appendix B.

THE MEASUREMENT PROBLEM

9. Many computing devices differ from other radio frequency devices regulated by the Commission in that they are usually composed of two or more interconnected subunits, with options for use of various accessories, and may be arranged in a variety of ways to better suit the intended use. Furthermore, they may be used with accessories not marketed by the supplier of the basic

equipment. Because of these factors, testing for assessment of interference potential of computing devices presents problems not often heretofore encountered with other devices regulated by the Commission. Experienced test engineers can resolve these difficulties, but since many of these tests will be new to a large number of engineers, the methods for resolving some measurement problems are documented here.

10. Much information has been gained concerning emissions from computing devices from the comments filed in Docket 20780 and from an examination of a variety of computing devices at the Commission's Laboratory. On the basis of the information thus obtained, it is understood that the spectrum of emissions from computing devices is composed of signals from three principal sources within the device. The time-base circuits generate a series of narrow-band signals that are harmonics of the time-base frequency or multiples thereof. Most data processing circuits generate a series of lower-level coherent signals that are more closely spaced in frequency than those emanating from the time-base circuitry. Control circuitry produces non-coherent broad-band noise signals (caused by relay closures, motor speed controls, etc.). The overall spectrum thus in the frequency domain appears to be a "comb" of individual coherent frequencies, with the time-base components usually higher in level (with some or all of these modulated in intensity by pulses generated in the system), plus a broad-band noise spectrum in the lower frequency part of the frequency domain. Although the first two of these components may appear to be a spectrum of broad-band random noise, such is not the case because all of these emissions are coherent and related directly or indirectly to the operations of the time-base and digital circuitry of the device.

MEASUREMENT PROCEDURE-GENERAL DISCUSSION

11. As indicated earlier, the procedure we are adopting adheres to long established methods of measurement. As explained in the NPRM , the proposed procedures essentially followed the American National Standard Methods of Measurement of Radio Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range 10 kHz to 1 GHz , ANSI C63.4, adopted November 10, 1980. 4/ The procedure we are adopting follows this standard with modifications based on the comments filed in this proceeding. Several other standards and recommendations were referred to by the commenting parties. Most notably, recommendations of CISPR were cited often.5/ Where an existing

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4/ Available from: Standards Department, The Institute of Electrical and Electronic Engineers, 345 East 47th St., New York, New York 10017.

5/ CISPR is the acronym for Comite International Special des Perturbations Radioelectrique (International Special Committee on Radio Interference). CISPR has adopted a number of recommendations for controlling interference from a variety of electrical and electronic components. CISPR recommendations are not mandatory, but have been adopted as national law by a number of foreign administrations.

standard or recommendation was considered, it is referenced in the pertinent paragraph of this Report.

12. Most commenters stressed the importance of flexibility in the procedures. The reasons are twofold. First, there is a wide assortment of equipments that fall under the definition of a computing device set forth in Section 15.4(n), of all shapes, sizes, and electrical configurations. Second, there are often constraints as to the resources (measurement equipment, test site, etc.) available. We agree that these are valid reasons for allowing flexibility in the measurement procedure and we believe that this philosophy was evident in the NPRM. Based on the comments received, we added additional flexibility in the procedure whenever it was possible. The specifications of what kinds of variations will be permitted in the procedure are addressed in subsequent paragraphs.

13. The test procedure for a device subject to certification shall be less flexible than for a device subject to verification. A Class B computing device subject to certification (i.e., personal computers and their peripherals) should be tested in accordance with the standardized procedure.6/7/ These devices have been established as having a higher likelihood of causing interference and their generally small size and fewer number of subunits should pose no particular measurement difficulty. On the other hand, equipments subject to verification--Class A equipments and Class B devices not subject to certification (i.e., digital watches, calculators, terminals, modems, printers, etc.)--have been found to pose a lesser potential for interference and we are willing to permit greater flexibility in their testing.8/ Also, we believe that the variability of arrangement and of component makeup of Class A computers is such that this flexibility is needed.

6/ 47 CFR 15.834 requires certification of coin operated video games, personal computers, and peripherals that are used with personal computers.

7/ Certification is one of the Commission's four equipment authorizations. It requires the manufacturer to submit a report of measurement along with an application demonstrating that the equipment complies with the pertinent technical standards. If upon review all is found satisfactory, a Grant of Equipemnt Authorization is issued which is the precondition for legal marketing in the U.S.A. The equipment authorization procedure is found in 47 CFR Subpart J of Part 2.

8/ First Report, paragraphs 10 thru 19.

MEASUREMENT PROCEDURE-SPECIFIC ISSUES

14. CBEMA suggested revision of some of the definitions in paragraphs 3.0 thru 3.10 and the addition of others. CBEMA recommended that narrowband noise and broadband noise be defined and with small differences the definitions they proposed have been added as new paragraphs 3.10 and 3.11, respectively. CBEMA also proposed a definition of peripherals. We concur that a definition of peripherals would be helpful, but believe that it should more appropriately be in the rules in Part 15.[9] With minor differences, the definition of a peripheral suggested by CBEMA has been added as a new Section 15.4(r). In light of CBEMA's suggestions, changes in language have been made in the definitions of Equipment Under Test, Line Impedance Stabilization Network and Conducted Radio Noise for purposes of clarification. The other definitions are adopted as proposed.

15. Several parties commented on test sites, which was the subject of Section 4.1 of the proposal. As mentioned previously, comments pertaining to test sites that have been filed in the instant proceeding are being considered in Docket 21371. Paragraph 4.1 has been changed to provide that open field sites to be used for certification measurements shall conform with the rules adopted under Docket 21371. While we suggest that open field sites used solely for verification measurements conform to those requirements in the interest of measurement accuracy, the Commission does not propose to require this nor to oversee prior approval of test sites used exclusively for verification measurements.

16. GE, HP, and CBEMA object to the stipulation in 4.1 that alternate test sites receive prior approval by the FCC. Prior FCC approval of an alternative test site was not contemplated. What was intended was Commission concurrence on the different types and applications of alternative test sites. To alleviate their concern, 4.1 is amended to make it clear that FCC approval of a test facility is required only for devices subject to certification. Atari, NTI, STC, and GTAE express concern that the procedure for correlation of an alternate site to an open field site is not defined and request further guidance in this area. This problem is particularly difficult to define and to make applicable for a wide, or even narrow range of alternative sites. Correlation technologies for alternative sites are being studied both by the government and industry and guidelines will be released as soon as they are brought to our attention. If a manufacturer is satisfied that a particular alternative site gives repeatable measurements that are correlateable to data taken in "open field" sites, the procedures are flexible enough to allow him to use such a site. However, measurements made by

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[9] See Reconsideration in Docket 20780, paragraphs 71 thru 77 for a detailed discussion on peripherals.

the Commission, should we decide to test a device (or system), will be made under the so-called open field conditions. Obviously, this does not apply to large equipments.

17. STC and NTI argue for the acceptability of anechoic chambers. There is no objection to their use; however, it must be recognized that it may be necessary to devise alternate test methods where the prescribed test procedure cannot be followed exactly (e.g., the height of some chambers may not allow the required 1 to 4 meter variation in receiver antenna height and thus may result in some measured differences.)

18. CBEMA suggests a change in title for 4.1.1.1. The title proposed reads Tests At Laboratory, Factory, or User's Premises. CBEMA requests that the last two words be changed to Other Facilities, to better reflect that a variety of alternate sites could be used. We have no objection and the change has been made. TI claims that its experience shows that correlation cannot be obtained between "open field tests" and on-site measurements but supports the Commission's proposal to accept tests made at a user's premises where open field tests are impracticable.

19. Drake-Willock, A-B, NEMA, CBEMA, EPT, and Atari commented on testing in a shielded enclosure, the subject of 4.1.1.2. The proposal stated that a shielded chamber could be used for preliminary tests, but that a shielded chamber is not suitable for determining compliance with FCC limits unless it can be shown that the results of tests made in the enclosure are correlateable to those made in an open field or equivalent site. Drake-Willock proposed that tests made in a shielded enclosure be accepted as demonstrating compliance since they are experiencing difficulty in obtaining a suitable open field site. Atari proposed that if test data showed that a device tested in a shielded chamber routinely radiated more than when tested on an open field, that testing in a chamber be permitted if data showed compliance with specification limits. NEMA also proposed that shielded chamber sites should be routinely acceptable. EPT supports the Commission's position that testing in a shielded chamber is not practicable for quantitative measurements. A number of sources indicate that as much as 20 dB difference may exist between measurement data taken in chamber and on an open field site for the same equipment.10/ The basic difficulty in establishing correlation is that the characteristics of the EUT itself have an affect on the correlation. We realize that in some instances where a group of EUT's is essentially identical from one unit to the next, that a

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10/ Keiser, Bernhard E, Principles of Electromagnetic Compatibility, Artech House Inc., 1979, pp. 315-317. The National Bureau of Standards (NBS) has also done work which indicates that the variation of radiated emissions measurements in a RF shielded chamber is on the order of 20 dB.

correlation is possible, as is exhibited in some military standards.11/ But for the devices which are the subject of this proceeding, the differences between equipments are sufficiently great to make a correlation improbable at best. In our view, the ordinary shielded chamber is most suitable for preliminary investigation of the spectrum signature of devices, as it eliminates problems with ambient interference.12/

20. CBEMA commented on 4.1.2, the section pertaining to testing at a user's installation (on-site testing), where the measurements cannot be correlated to those which would be obtained at an open field site. They proposed that where three systems representative of a type have been tested at different user's installations and found to be in compliance, that this be considered to be sufficient evidence of verification for that type of system. The benefit to be gained by adopting this proposal would of course be a lessening of the test burden in many cases. The risk appears to be minimal since compliance at three installations should be fairly representative of what may be expected at other installations. We, therefore, accept this proposal and 4.1.2, 4.7, and 6.3 have been amended accordingly. Also, 4.7 and 6.3 were revised to eliminate a conflict between the measurement distances stated in those paragraphs as contained in the NPRM. We have accepted CBEMA's proposal that the title of 4.1.2 be changed, deleting the term "(ON-SITE TESTING)" in order to eliminate possible confusion with other references to open-field testing where this term has been used elsewhere in the Rules.13/

21. Texas Instruments commented on Section 4.1.3, Individual Equipment Test Requirements. The intent of this section is to allow manufacturers the freedom to develop a test method to suit a unique or unusual EUT. The proposed section included a stipulation that the procedure be found acceptable to the FCC. Texas Instruments suggests deletion of 4.1.3 saying that applicants may always request a waiver of the rules based on a showing that the test procedures are inappropriate for a specific type of equipment. AT&T objected to the TI proposal due to the delay, cost, and general burden of the waiver process. We agree with AT&T that the need to file for a waiver each time a unique or unusual measurement problem arises would be overburdensome. Therefore, we are retaining the original language.

11/ EUT is used throught the report as an acronym for Equipment Under Test.

12/ Biagini, Chris, Open Area Site and Laboratory Testing for Computer Type Equipment, a paper given at the 1980 Midcon Professional Program, November 4-6, 1980, at pps. 4-6. Discusses preliminary measurements in shielded chambers.

13/ The term "on-site certification" is used in 47 CFR 2.1037 and pertains to authorization of industrial, scientific, and medical equipment at a given installation.

22. Proposed paragraph 4.2, Measuring Instrumentation, required that a spectrum analyzer be used for measurements with a field strength meter meeting ANSI C63.2 specifications an acceptable alternative. CBEMA, AT&T, EPT, GE, Bronaugh, and Banasiak proposed that this be changed to specify the ANSI C63.2-1980 instrument, with the spectrum analyzer as the alternative. These parties explain that the field strength meter is specifically designed for making field strength and other radio emissions measurements as opposed to a spectrum analyzer which is a general purpose instrument. There are several characteristics of the radio noise meter which are advantageous in making electromagnetic interference (EMI) measurements. These are the dynamic range, overload capabilities, selectivity characteristics, capability for battery operation, choice of several standardized detector functions, and general ease of operation.[14] In light of the comments, we concur that the field strength meter is the instrument of choice when available. The language in 4.2 is revised accordingly. A spectrum analyzer can be used as an alternate instrument. Hewlett-Packard points out that when using the spectrum analyzer, in order to obtain accurate measurements it may in many cases be necessary to use accessory equipment (filters, low noise amplifiers, etc.) Notes have been added to 4.2 to cover the points raised by HP and others.

23. Several comments were filed concerning detector function selection and bandwidth in 4.2.2. As proposed in the Notice, measurements were to be made with the measuring instrument set for peak, or alternatively the CISPR quasi-peak detector function. This is a change from previous rulemakings in which the evaluation of the interference potential of devices was made with average-value measurements. In those earlier devices, their emissions were in general narrow-band, with little or no modulation, so that their interference effects were reasonably related to their average value. In the case of computing devices, however, although most of their emissions are relatively narrow-band, they are usually modulated with pulses originating from the timing or data processing circuitry, so that their interference effects, particularly to television reception and to reception of data transmissions, are more nearly related to their peak values. The pulse response characteristics of the CISPR quasi-peak detector circuit were developed specifically to weight the readings to approximate the human audio and video response characteristics.

24. GE recommends use of an average detector. While GE concedes that a peak or quasi-peak detector may be more appropriate for measuring emanations from computers, it explains that an average detector will in many instances give a much lower reading and goes on to imply that the limits that were adopted presupposed use of the lower reading average detector. GE does

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[14] Bronaugh, pages 3 and 4.

not develop the details of this argument, but refers to the CBEMA/ESC5/77/29 report.15/ The Commission explained in the First Report in Docket 20780 that the limits it was adopting for computers are in line with the limits developed in the CBEMA report.16/ A review of the CBEMA report shows that we have been consistent with CBEMA's recommendation on detector function. See Figure 8-3 of that report. In the comments filed in the instant proceeding, CBEMA supports the proposal with regard to detector function and bandwidth for radiated emissions. We, therefore, find GE's suggestion to be without basis.

25. EPT questioned why provision was made for use of a quasi-peak detector designed to CISPR standards and not for quasi peak detectors designed according to other standards. As explained in the First Report in Docket 20780, many computing devices are sold abroad and subject to European standards which by and large follow CISPR recommendations. It would be more economical for all concerned if the standards are essentially uniform from one country to the next and we support this end. We have therefore specified the CISPR quasi-peak detector. Other quasi-peak detectors may yield different results and this is the reason that multipicity is not acceptable.17/ Banasiak calls attention to the fact that the peak and quasi-peak detectors can give different results. While this is correct for broadband emissions, most computing devices exhibit emissions which are narrowband with respect to the specified bandwidth and as a result there is little or no difference in data obtained with either detector. For certain devices which exhibit a preponderence of broadband spectra, a quasi-peak detector may be advantageous. In general, however, the results using either the CISPR Quasi-Peak or Peak detector will be approximately the same for most devices.

26. There is another reason for allowing a choice of detectors. While we are interested in promoting harmonization of standards and therefore accept the use of the CISPR detector, we also recognize that such instruments have not previously had widespread use in this country. On the other hand, test instruments with the peak detector, such as spectrum analyzer, are widely used by manufacturers. Therefore, a choice of detectors, since both produce essentially the same results for most devices will permit maximum flexibility. An individual who prefers using the CISPR instrument will find that several manufacturers of popular EMI instruments are now offering adapters that permit a number of currently available instruments to meet the CISPR specifications. This problem concerning the

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15/ Limits and Methods of Measurement of Electromagnetic Emanations from Electronic Data Processing and Office Equipment, CBEMA/ESC5/77/29 submitted with additional filing on June 16, 1977 as a comment in Docket 20780.

16/ See First Report, paragraph 53.

17/ ANSI C63.2-1980, page 15.

availability of CISPR instruments should diminish soon.

27. On power line conducted emissions measurements, CBEMA and GE object to use of a peak or quasi-peak detector. In connection with this, both refer to the First Report in Docket 20780 and explain that it is their understanding that the Commission has not adopted limits for broadband conducted emissions.18/ This is inaccurate. The limits that were adopted do apply to broadband emanations; however, we are still studying the problem.

28. In the interim, to provide some degree of protection from interference caused by broadband emissions, we are adopting a solution proposed by CBEMA, with some changes. Measurements are first to be made with the instrument set in the peak or quasi-peak mode using a bandwidth of 9 kHz or greater. 19/ If signals are found which exceed the FCC limits, further measurements may be made using an average detector. If the reading significantly changes , the emission may be considered broadband and the reading in the quasi-peak mode may be reduced by 13 dB for comparison to the limits. CBEMA suggests that for narrowband/broadband limit equalization, the adjustment should be 20 dB. This appears to be unreasonably high. It is our understanding that this problem is being considered by the International Electrotechnical Commission (IEC), under the auspices of CISPR Subcommittee B Working Group 2 (CISPR/B/WG2), of which CBEMA is a member, and at this time the adjustment between quasi-peak or peak and average readings is seen to be approximately 13 dB. We consider 13 dB to be more reasonable than the 20 dB suggested by CBEMA and will use it until this matter is investigated further. A NOTE is added to paragraph 4.2.2 in accordance with the above discussion.

29. GE and Bronaugh point out that 4.2.2 is not as complete as ANSI standard C63.2-1980 as to the variance permitted on the specified instrument bandwidth. Paragraph 4.2.2 specified a minimum instrument bandwidth of 9 kHz for measurements over the range 0.15 to 30 MHz and a minimum instrument bandwidth of 100 kHz for tests in the range 30-1000 MHz. In light of the comments, a note is added to 4.2.2 to call attention to the fact that there is a bandwidth tolerance and refer to ANSI C63.2-1980.

30. Motorola, EPT, and AT&T request that provisions be made for instrument bandwidths of less than 100 kHz for radiated emissions measurements over the range 30 MHz to 1000 MHz. Motorola and EPT cite improved signal to noise ratios for weak signals as the grounds for such provisions. AT&T explains that in some instances the closest available bandwidth is slightly below what is allowed and that the next higher instrument

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18/ First Report paragraph 56.

19/ CBEMA comments, dated September 2, 1980, Appendix A, pages 10 and 11.

bandwidth is such that it will give readings 20 dB too high. In reply to these comments, CBEMA states that

> "...such latitude can only be accomodated if correction factors are uniformly utilized by the tester to account for the inadequacy of the narrower bandwidth receiver in measuring other than narrowband emanations. In other words, if bandwidths narrower than those already specified in the proposed standard are to be utilized... a correction factor equal to the ratio of the specified bandwidth to the narrower bandwidth actually utilized must be applied to the results..."20/

It is our opinion that permitting lesser bandwidths introduces uncertainties into the measurements as evidenced in CBEMA's comments. The correction factor suggested by CBEMA is not substantiated and does not appear to be uniformly applicable regardless of the emission. We, therefore, are retaining the 100 kHz minimum bandwidth requirement. AT&T and CBEMA requested that the bandwidths be specified as 6 dB bandwidths for clarification and 4.2.2 is amended accordingly.

31. Yamaha requested a revision of 4.2.3, Units of Measurement. As proposed, this paragraph specified data presentation in terms of microvolts for conducted measurements, or microvolts per meter for radiated emissions. Yamaha requested that this be changed to permit reporting in dB above 1 microvolt for conducted tests and dB above 1 microvolt per meter for radiated tests, as alternates. These units are in general use in measurement reporting. We have no objection and 4.2.3 has been revised accordingly.

32. Several comments were filed concerning proposed paragraph 4.2.4, Antennas. This paragraph specified use of a calibrated half-wave dipole as the measuring antenna, with other linearly polarized types of antennas to be acceptable alternates. NTI requested that use of broadband antennas be permitted (bi-conical, log-spiral, circular, or dual polarized). AT&T, HP, and NTI recommended changes to permit use of antennas other than linearly-polarized. Calibration of linearly polarized broadband antennas such as bi-conical and log periodic is such that measurement results can be related or correlated to those obtained using the half-wave dipole. Accordingly, bi-conical and log periodic broadband antennas may be used when properly calibrated. On the other hand, circularly polarized broadband antennas, such as the log spiral antenna, are not suitable for these types of measurements. The radiation from the equipment under test is randomly polarized and emerges from more than one source (in most instances) and it may on some

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20/ CBEMA reply comments, pages 10 and 11.

frequencies approximate circular polarization. If this should be of the opposite rotation to that for which the antenna was designed, the observed signal strength would be much less than that actually present. We are, therefore, retainng the specification for use of linearly-polarized antennas for measurements and the log spiral antenna is not considered acceptable for determining compliance with the limits (although it may be employed for preliminary scan measurements). CBEMA proposed that below 80 MHz, the length of the dipole be adjusted to that for 80 MHz rather than the half-wave value. There is no specific objection to this providing that a correlation is shown and the values adjusted to what would be obtained with a half wave dipole.

33. Comments on the requirement of 4.2.4, Antennas, that the height of the measuring antenna be varied to obtain the maximum radiated signal, were filed by CBEMA, Atari, HP and EIA/CEG. Atari and HP proposed that measurements be made with the measuring antenna at a fixed height. Two reasons are given. The first is convenience. The second has to do with difficulty in meeting this requirement at certain alternate sites such as anechoic rooms. The Commission cannot accept this suggestion. The practice of varying the height of the measurement antenna is of long standing and is called for in numerous measurement standards such as IEEE 187 21/, EIA RS 378, 22/ and IEC 106/106A. 23/ ANSI C63.4-1980 also calls for varying heights to obtain a maximum reading. The emitted signal travels to the measurement antenna by both a direct and a ground reflected path. The relationship of the two signals is different at different points of space (they may add or cancel), and for several reasons one cannot, from a practical standpoint predict the points--heights above ground--at which the signals will add in a maximized manner. One reason is that the radiation emerges from the equipment from a variety of points and with random phase. Another reason is that the ground properties, which affect the ground reflected ray, may vary from one site to the next. Thus, experience has shown that the maximum signal

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21/ IEEE 187, Standards on Radio Receivers: Open Field Method of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receiver, 1951 available from the Institute of Electrical and Electronic Engineers, 345 East 47th St., New York, New York 10017.

22/ EIA RS 378, Measurement of Spurious Radiation from FM and TV Broadcast Receivers in the Frequency Range of 100 to 1000 MHz-Using the EIA-Laurel Broadband Antenna, available from Electronics Industries Association, 2001 Eye St., NW, Washington, DC 20006.

23/ IEC 106/106A, Recommended Methods of Measurements of Radiation from Receivers for Amplitude-Modulation, Frequency-Modulation and Television Broadcast Transmissions, available from the American National Standards Institute, 1430 Broadway, New York, New York 10018.

determined by varying the height of the measuring antenna gives more consistent results with a smaller degree of variation between sites. A procedure that uses a fixed height for the measuring antenna can be expected to yield a more random result with a much higher degree of variability from site to site. Accordingly, we cannot accept the proposals to use a fixed height for the measuring antenna for open field sites and have retained the requirement for variation of the height of the antenna with two changes. AT&T rightfully points out that in some cases of vertical polarization undesirable antenna coupling effects will occur as the bottom tip of the antenna approaches ground. Accordingly, the specification for height variation has been changed to provide a minimum clearance of 25 cm from ground for the bottom end of the antenna in the case of vertical polarization. Also, EIA/CEG proposed that the height variation of the antenna on a 30 meter site be limited to a maximum of 6 meters instead of the proposed 7 meters in order to conform to EIA Standard RS-378. 4.2.4 is revised accordingly. Insofar as the problem antenna height variation poses with regard to anechoic rooms, or other alternative sites, language is added to 6.2 to provide for fixed antenna heights where it can be shown that equivalent results are obtained.

34. CBEMA aserts that the radiated emissions limits that were established for computing devices in Docket 20780 depended on the measurement antenna being located at certain fixed heights. They go on to say that a measurement procedure where the antenna height is varied would in effect invalidate the limits. This is a fallacious argument.[24] The rationale for the limits is given in Appendix C of the First Report in Docket 20780. (The derivation is essentially the same as one used by CBEMA in its report CBEMA/ESC5/77/29).[25] Appendix C of the First Report shows that the limits are based on a prediction of field strength present at the susceptible receiver's antenna, the source of which is a signal emitted by a computing device at a horizontal distance of 10 meters. This prediction involves general approximation of the attenuation of the signal travelling through space from the computing device to the receiver's antenna. This is done of necessity because of the full range of unpredictables that disallow an exact approach: height relationship of receiving antenna to radiating device; direction of radiated emission; different compositions of intervening walls; properties affecting propagation differing at each installation etc...CBEMA in its ESC5 report takes the approach that a generalization can be made concerning the heights of susceptible receivers' antennas. CBEMA states:

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[24] In the First Report in Docket 20780, paragraph 62, a simplified description of the test procedure was given. This description included varying the height of the measurement antenna to maximize the received emission.

[25] CBEMA/ESC5/77/29, pages 7-6 thru 7-8.

> The relative height of EDP/OE installations and VHF/UHF antennas was found to vary between -9 and +77 meters. Half (50%) of the antennas were located at a relative height of -7.7 to +14 meters. Ten meters was therefore picked as a typical control height for radiated emanation limits.26/

CBEMA develops this for determining fixed measurement heights for the measurement antenna at various test distances. It is implied by CBEMA that these height/distance relationships are critical to the approximation for attenuation (that the signal decreases in direct proportion to the inverse of the distance) that CBEMA reported and the Commission similarly used. This is not the case. The inverse distance approximation for attenuation of the signal through space is widely recognized and is reflected in existing standards such as IEEE Standard 187 and EIA Standard RS-378 where the measurement antenna is varied in height to find the maximum signal level at each distance.27/ A basic flaw in CBEMA's argument is that a single height antenna does not well represent the profile of signal levels that may exist at the full range of receiver antenna heights that occur in the real world. In further support of its argument, CBEMA furnished a pre-publication copy of a paper by Robert F. German and Ralph Calcavecchio, title On Radiated EMI Measurement in the VHF/UHF Range, which indicates that a 1.5 meter antenna height may be appropriate at a 3 meter measurement. In reviewing the paper, we find that it is based in part on assumptions not representative of what occurs in testing computing devices, such as treating the equipment as an essentially point source radiator. Also, the paper is not supported by actual measurements. While we agree that testing at one antenna height is attractive in that it simplifies the task and more readily permits automation of testing, it unfortunately has the above stated handicaps. It also leads to results which cannot be correlated when extrapolating test data from one distance to another. Alternative techniques, such as one suggested by HP, are being investigated but until an acceptable method is found the present antenna search will be retained in the procedure.

35. It came to our attention in reviewing the comments that there was a need for providing for test distances other than 3, 10, and 30 meters. We have amended the sections of the procedure pertaining to this area. Basically, measurements made at one distance can be extrapolated to the limit distance by assuming an inverse distance extrapolation factor. Insofar as antenna height variation, we have established a break point at a test distance of 10 meters beyond which the height variation must be 2 to 6 meters. At 10 meters and closer the height variation is to be 1

26/ CBEMA/ESC5/77/29, page 6-6.
27/ See footnotes 16 and 17.

to 4 meters. This relaxes the proposal where measurements at 10 meters called for a height variation of 2 to 7 meters.

36. There were several comments filed concerning how the equipment should be configured during the radiated emissions tests. Information on equipment configuration for radiated tests was given in proposed Paragraphs 4.2.5, 4.5, and 4.7. EPT proposed that an attempt be made to standardize the test configuration rather than attempt to maximize the emissions by rearrangement of the cabling and other accessories. EPT did not recommend a specific configuration. The Commission has given extensive consideration to the subject. A standard test configuration is certainly desirable because it would be easier to repeat the measurements; however, there is great diversity in the equipments that are subject to the computing device requirements and it appears for this reason that an attempt to develop a standard test configuration for all equipments, or even a majority of equipments, would not be practical. A statement was made by EIA/CEG that the language should better define how cables or accessories are to be handled. TI proposed that arrangement of the equipment simulate actual use rather than to attempt to set up the equipment to maximize its emissions. As explained in paragraph 33 above, it is our belief that under the circumstances the only meaningful measurement approach is one involving maximization of the emissions characteristics. We wish to make it clear that we do not expect the tester to go to unreasonable lengths to find the maximum. An individual experienced in making EMI measurements should have no difficulty in maximizing the level of emissions from a device. In general, the affects of rearrangement of peripherals, cabling, etc. are apparent within a short period of time by observing the measurement instrument while the items are moved. In light of the comments, we have amended 4.7 to state that excess lengths of cables are to be bundled at the approximate center of each cable by folding back and forth so as to form a bundle not exceeding 30 cm to 40 cm in length. This provides some degree of uniformity. Atari suggested that the language in 4.7 be changed to make it clear that only reasonable configurations need be investigated. 4.7 is changed accordingly. Banasiak objected to the requirement for use of a LISN during the radiated tests saying that in many cases it serves no useful purpose. We have reviewed ANSI C63.4-1980 and found that a LISN is optional for radiated emissions tests. We have amended Figure 2 to clarify the optional nature of the LISN.

37. The proposal called for reporting all emissions within 20 dB of the specification limit. This was set forth in 4.3, Frequency Range to be Scanned. It was suggested by AT&T and HP that this be changed to 6 dB. CBEMA proposed recording a representative number of emissions. The basic problem is that in some instances there are a high number of discrete emissions which approach the limit, and in these instances an inordinate amount of data would have to be reported under the proposal. Also, it would probably be difficult to comply with a 20 dB

reporting requirement because of instrument sensitivity and noise limitations. We feel that a 6 dB requirement would be too lax and lead to insufficient investigation of the emitted signals. Also, if only emissions within 6 dB of the limit were reported, in many instances no data whatsoever would be furnished. In considering the matter further, we have decided to revise 4.3 to require reporting only the six highest emissions relative to the limit. In this way the data required to be reported can be held to a reasonable amount and the spectrum signature of the device will be characterized to some extent.

38. EPT, NEMA, A-B, Banasiak, and Rockwell expressed views to the effect that the proposed procedure is not well suited for testing large systems comprising a number of units, sometimes referred to as distributed systems. The basic problem lies in the fact that a basic system is packaged with varying numbers and types of peripherals to suit each customer's needs. EPT calls attention to the fact that many master controllers are connected to varying quantities of slave units. Rockwell suggests testing a single representative operating system (in other words the basic starter system), thereby establishing the emissions characteristics of the basic cabinets. Optional equipment would be tested separately while connected to either a host controller or simulator. This approach seems reasonable to us but we wish to make some additional comments. It is preferable that the basic system be tested with as many of the optional peripherals as possible to minimize any additional testing. Also, in the instance where several of one type of peripheral (all exactly identical) are utilized with a single controller, only one need be tested. We have inserted a new 4.5 to include this provision. 4.5 of the NPRM is renumbered 4.5.1 with subsequent paragraphs also renumbered as necessary.

39. There are two subjects covered elsewhere in this report which are of special interest where large systems are concerned. Banasiak explains that for large systems rotation of the EUT would be difficult, if not impossible. This circumstance is provided for in 6.1, as described in paragraph 48 below. Briefly, the EUT would be left stationary and the measurement equipment moved around it. Attention is also invited to 4.1.2 which pertains to the case where tests at the user's installation are not correlateable to open field measurements. Tests at three such installations are, under 4.1.2, considered adequate for verification purposes.

40. Motorola and EIA/CEG contend that there is no need for reporting the EUT warmup time as would be required under proposed paragraph 4.5.1--now renumbered paragraph 4.5.2. They point out that a similar requirement does not exist for other devices subject to tests for Commission purposes and no particular difficulty has arisen. In light of these objections we are amending 4.5.2 to drop the requirement for reporting warmup time. Comments were also filed regarding the requirement of 4.5.1 that devices be operated at the specified load conditions

(mechanical and/or electrical) for which it is designed. EPT points out that there is a general lack of information available from manufacturers on the RF impedance of input/output busses of equipments subject to testing, nor is this information available for the devices to which they interconnect (i.e., peripherals). We believe that information as to load conditions must be available to or assumed by equipment designers, so that the device can operate within design criteria. Therefore, this requirement is being retained.

41. Atari asserts that there is a potential inconsistency in 4.5.4, now renumbered 4.5.5, as to the grounding of the EUT. The first sentence of the proposed paragraph states that the EUT should be grounded pursuant to the manufacturer's requirements and conditions of intended use. It also specifies that any internally-grounded lead included in the plug end of the line cord shall be connected to ground through the utility power service. Atari points to the case where on some test sites the EUT may be powered by a long extension cable. They contend that this is not representative of conditions of intended use and that grounding through the long power cord may lead to excessive radiation. Atari proposes that an alternative ground be used in such cases. While we recognize that the situation described by Atari is less than ideal, we do not agree that a conflict exists. It is not unusual for an equipment to be powered through an extension cord. To permit alternative grounding would, in our opinion, introduce uncertainties in the measurement and not be representative of normal installation. Therefore, Atari's proposal for alternative grounding is rejected and the subject section is adopted as proposed.

42. Paragraph 4.5.3, Interfacing Units and Simulators, now renumbered as paragraph 4.5.4, drew several comments. This item provided for testing peripherals while connected to a simulator or exerciser in lieu of a computer. The stipulation is that the simulator represent the electrical and in some cases the mechanical, characteristics of the interfacing unit, especially concerning RF signals and impedances. EIA/CEG suggests that this section be deleted because it is too broad and subject to misinterpretation. Supporting details are not given. We feel that elimination of this paragraph is not the proper approach. CBEMA, Atari, and other commenters in general, supported the provision for testing peripherals with a simulator. In our opinion, it is appropriate to set forth only general criteria that a simulator should meet because of the diversity of simulators that might be used. Where questions come up as to whether a simulator is suitable for a specific application, concerned parties are encouraged to contact the Equipment Authorization Branch for guidance.28/ Atari supports the use of

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28/ Equipment Authorization Branch, Office of Science and Technology, Federal Communications Commission, P.O. Box 429, Columbia, Maryland 21045; telephone (301) 725-1585.

simulators but cites a possible area of confusion in the language. Atari refers to the statement that simulators must represent the characteristics of an actual interfacing unit "...especially concerning RF signals and impedances" and claims that this could be read to require that simulators function so as to radiate RF emissions comparable to that produced by an interfacing unit. We do not believe that there is a significant problem in this area, particularly in light of the fact that no similar comments on this subject were filed. CBEMA recommends the addition of language to make it clear that a peripheral need not be tested with more than one simulator. Paragraph 4.5.4 is amended accordingly.

43. In 4.6.1, Ambient Radio Noise and Signals, it was suggested that test sites have levels of conducted and radiated radio noise at least 6 dB below the allowable radiation limits. Several methods are suggested in 4.6.1 for showing EUT compliance where the ambient field at the specified distance does not meet this criteria. This item drew considerable comment. STC said that they could not locate a site sufficiently free from high ambient signals. Atari commented that the 6 dB provision would preclude use of most sites. CBEMA also addressed this problem and suggested language to clarify the discretionary nature of the procedure in this regard, leaving more flexibility to the manufacturer to overcome particular high-ambient-level problems in some frequency ranges. In the proposal, the Commission indicated that the 6 dB provision was a desireable criterion but not a mandatory one. By suggesting various ways in which measurements could be made in the presence of interference, it was believed to be apparent that sites might be used in spite of high ambient interference. 4.6.1 has been rearranged in light of the comments. In line with CBEMA's suggestion, a sentence has been added that the alternatives mentioned are only some of those available. As suggested by STC, the statement regarding supplemental measurements being made in a shielded chamber or anechoic room has been expanded to say that the measurements made at the open field site may be supplemented with indoor measurements to demonstrate compliance if high ambient conditions exist at the open field site.

44. A number of comments were filed concerning the height of the test platform. This topic is covered in proposed Section 4.7, Arrangement of EUT (On Test Stand). In the proposal, test stand heights were specified for both table-top and floor mounted equipments. AT&T, HP, and CBEMA proposed stand heights somewhat different than that in 4.7, on the grounds that the alternate heights better represent the heights that would be encountered in actual use. HP contends that the results will be affected by as much as 14 dB by the height above the floor of the EUT, but their argument assumes a fixed height for the measurement antenna. The procedure we are specifying includes variation of the height of the measurement antenna and when this is done the height of the EUT is not critical. The heights chosen in the FCC proposal are essentially in agreement with those in existing measurement

standards, in particular IEEE Standard 187. 29/ In the case of table mounted devices, we proposed a test stand height of approximately 1 meter, and for floor standing equipments, a test stand height of no more than 0.45 meters. We emphasize that the language provides for some variation from the 1 meter or 0.45 meter heights. For example, a floor standing equipment could be located at any convenient height between 0 and 0.45 meters above ground. The arguments of AT&T, HP, and CBEMA for changing the specified heights are not in our view adequate justification for creating a situation where different test stand heights would be required for table top computing devices than for other table top RF equipments. This would pose a particular problem at sites used for testing both computing devices and other equipments. Accordingly, we have retained the proposed test stand heights. HP referred to difficulty in building rotatable platforms that are portable and 0.45 meters in height. We believe that this is a solvable design problem. Turntables meeting the specified parameters have been constructed by a number of individuals. Some changes in language in 4.7 have been made for purposes of clarification in line with suggestions made by CBEMA and HP.

45. The NPRM proposed that a ground plane be mandatory for 3 meter sites and optional for others. Several comments were filed on this issue but it will be covered in the upcoming action in Docket 21371. We have eliminated the mandatory requirement for a ground screen in the instant proceeding and 4.8 is amended accordingly.

46. In 5.1, Conducted Powerline Test Configuration, it was proposed that hand-held devices be tested when supported by an "artificial hand" to simulate effects of body contact to the user. Atari, TI, and EPT objected to this, proposing that these be tested as desk-top units. EPT also pointed out that the signal level is affected by proximity of the operator's fingers to the keyboard on some devices, and that no mention of this was made in the proposal. The proposal to test hand-held units as if used on a desk is acceptable, and 5.1 is changed accordingly. In the Notice, we did not attempt to account for hand capacity effects because it was felt that these were generally very difficult to quantify, and that any additional interference effects due to this could probably be tolerated since hand keying is relatively intermittent except for word-processing equipment. An amendment is made to 5.1 to clarify that where computing devices or their peripherals have their own provision for connection to a power line, line conducted tests must be performed separately for each device. This is to preclude measuring several devices together through a single LISN because the results may then depend on the unique characteristics of that arrangement and there is no assurance that those same devices will always be connected together in actual use.

29/ Footnote 16, supra.

47. Paragraph 5.3, Line Impedance Stabilization Network, proposed use of a 50 microhenry line impedance stabilization network (LISN), to conform to the ANSI C63.4-1980 standard and to the latest CISPR recommendation. It cited Figure 3 as showing the impedance characteristic and Figure 4 as showing the circuit diagram of this network. (Note: Figures 3 and 4 are now Figures 2 and 3, respectively.) Figure 3 was redrawn from ANSI C63.4-1980, and Figure 4 was a reprint from that standard. GE and Mobley pointed out that calculation based on the nominal circuit values shown in Figure 4 did not agree with the curve shown in Figure 3. This was referred to ANSI C63.4-1980 for comment and ANSI has revised their curve. Figure 2 is a redrawn version of the old Figure 3 to reflect the proper impedance curve. Motorola objected to the exclusive use of a 50 microhenry LISN network because the 5 microhenry network has been in use for several years and is required for testing other equipments. GE pointed out that use of the 50 microhenry network instead of the 5 microhenry one referenced in previous technical standards would cause a substantial increase in measured levels in the region just above 450 kHz. This factor was considered in setting the specification limits for line conducted emissions in Docket 20780. 30/ Recognizing that the 50 microhenry network is not yet readily available on the market, and that many parties already have in use the older 5 microhenry networks, we have added a note to 5.3 to permit interim use of the 5 microhenry network providing that appropriate corrections are made to the measured values below 2 MHz to give values equivalent to those which would have resulted if the 50 microhenry network had been used. A correction curve is appended to the procedure as Figure 5.

48. Information on the subject of azimuth angles to be investigated in making radiated emissions measurements was contained in Paragraphs 4.7, 6.1 and 6.2.1. Paragraph 6.1 called for measurement of the magnitude of each "predominate" emission in the azimuth direction of maximum field strength. Paragraph 4.7 said essentially the same thing. In Paragraph 6.2.1 the requirement is that frequency scans of the EUT radio noise emissions shall be made at a minimum of eight azimuth angles spaced at 45 degrees. Atari and EPT are in favor of amending 6.1 to specify a fixed number of radials and they suggest eight. CBEMA, NTI, and Drake-Willock are opposed to this because it would necessitate recording a large amount of data and would not be consistent with a flexible measurement procedure philosophy. Our objective is to see that the emission is measured in the direction where it is at its highest level. In considering this matter further we have decided not to specify how many radials need to be checked; instead, we are leaving it to the discretion of the person performing the tests to determine how many radials should be checked to locate the direction of maximum radiation. Paragraphs 6.1 and 6.2.1 have been conformed in this regard. The information in 4.7 is redundant and has been eliminated.

30/ First Report, paragraph 58.

49. As originally proposed in the Notice, Paragraph 6.3, Testing of User's Installation, called for measurements at the premises boundary or 30 meters, whichever the greater distance. It was brought to our attention by CBEMA and others that the premise boundary may in some instances be much more than 30 meters from the computer system. In light of this we are amending Section 6.3 to call for measurements at 30 meters or less from the EUT (in which case the data must be extrapolated to 30 meters). This is consistent with Paragraph 4.7 of the procedure.

PROCEDURAL MATTERS

50. Arrangements are being made for the appended FCC Methods of Measurements of Radio Noise Emissions from Computing Devices, (Appendix C) to be published by the National Technical Information Service (NTIS) of the U.S. Department of Commerce. An FCC public notice will be issued to explain how the document may be obtained from NTIS.

51. AT&T and CBEMA proposed that the computing device test procedures be incorporated in the FCC Rules rather than issued as a separate document. The concern of AT&T and CBEMA is that allowing or requiring variances in the critical elements of the measurement procedures can effectively change the appropriately adopted limits. The procedures are incorporated by reference in accordance with procedures established by the Federal Register. Any substantive changes in the test procedure will require advance notice in accordance with the procedures established under the Administrative Procedure Act, 5 USC 551-553. The reason for publication of the test procedure as a document separate from the Rules are convenience and economics. Increasing the size of the Rules invariably leads to an increase in their cost. There are many parties having devices subject to rules in Part 15 who would not be interested in the computing device test procedure. We do not anticipate any particular difficulty with regard to availability of the standard from NTIS. In view of this we are holding to our plan to publish the standard through NTIS.

52. A number of parties inquired about how they will be able to find out about alternative or special test procedures that the Commission has accepted so that they may also utilize them. The Commission has established a computing device panel to answer questions pertaining to the computing device rules.31/ Interpretations issued by this panel that are of significant importance are made known through FCC public notices. A bulletin is being prepared which will bring these interpretations together in one document, and present them in representative question and

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31/ Announced in a public notice dated May 7, 1980-G, mimeo #31367.

answer form. It is our intent to publicize significant alternative test procedures in the same manner; that is, by public notice and eventual inclusion in updated versions of the computing device interpretations bulletin.

53. The NPRM solicited comments as to whether the proposed test methods might in a future proceeding be used, with appropriate modification, for testing other devices subject to FCC emission requirements. Although EIA/CEG supported this concept, the commenters had little else to say on this subject. The matter may be addressed again at a later time.

SUMMARY AND CONCLUSIONS

54. The requirements for verification adopted herein are merely a formalization of what was said in the First Report in Docket 20780 as to the way in which manufacturers may themselves assure that their equipments comply with the standards for computing devices. Verification is a self-approval procedure. Notification or approval of the Commission is not necessary.

55. Part 15 is amended to cite the measurement procedure appended to this report as the test methods to be used in determining compliance with the requirements for computing devices as set out in Part 15 Subpart J. These test methods are designed to yield accurate and repeatable results for comparison to the appropriate limit. While the test methods are to a degree standardized, enough flexibility is built into the procedure to permit it to be adapted to suit unique or unusual measurement situations.

56. The procedure principally covers two kinds of measurements: radiated emissions tests and power line conducted emissions tests. The radiated emissions test is to be performed on an open field or equivalent site. The unit to be tested is set up on a platform. An antenna is placed at some distance away and connected to an instrument which measures the strength of the signal emitted by the device. The device is rotated and the antenna height varied to obtain a maximum reading. The power line conducted test is performed indoors. The measurement instrument and device under test are connected through a standardized line impedance stabilization network (LISN). The results can be read directly on the measurement instrument.

57. The schedule for use of the appended test methods is set forth in Section 15.840. Simply stated, as of July 1, 1981, the appended procedures are to be used for testing computing devices. This is considered to be an adequate period of time to conform to the new standard since the standard does not require facilities over and above what was called for in the interim procedures discussed in the First Report in Docket 20780. Prior to July 1, 1981, devices may be tested either using the appended procedure or using the interim procedures referred to in the

First Report in Docket 20780. Manufacturers should note that devices that have already been verified or certificated using the interim measurement procedures do not require retesting under the new procedure.

58. Pursuant to the authority contained in Sections 4(i), 302 and 303(r) of the Commuications Act of 1934, as amended, IT IS ORDERED that effective , Parts 2 and 15 are amended as set out in Appendix B, attached.

59. IT IS FURTHER ORDERED that the measurement procedure in the attached Appendix C is adopted as the procedure to test computing devices as defined in Part 15, Subpart J.

60. For further information about this ORDER, contact Mr. Julius Knapp, Office of Science and Technology, Federal Communications Commission, Washington, DC 20554, phone 202-653-8131.

FEDERAL COMMUNICATIONS COMMISSION

William J. Tricarico
Secretary

Attachment

APPENDIX A

I. The following parties filed comments in Docket 80-284:

Name/Organization	Acronym
Rockwell International	Rockwell
Texas Instruments	TI
Joseph Banasiak, PE	Banasiak
General Electric	GE
Hewlett-Packard	HP
American Telephone and Telegraph Co.	AT&T
Atari, Inc.	Atari
Storage Technology Corp.	STC
Northern Telecom Inc.	NTI
Motorola	Motorola
Electronic Products Testing, Inc.	EPT
Edwin Bronaugh	Bronaugh
Electronic Industries Ass'n/Consumer Electronics Group	EIA/CEG
Computer & Business Equipment Manufacturers Ass'n	CBEMA
ICL, Inc.	ICL
B-D Drake Willock	Drake Willock
Microcomputer Industry Trade Ass'n (MITA)	MITA
Yamaha Music Manufacturing	Yamaha
Milton Mobley, Consultant	Mobley
GTE Automatic Electric Inc.	GTEAE
Allen-Bradley	A-B

II. The following parties filed reply comments in Docket 80-284:

Name/Organization	Acronym
Computer and Business Equipment Manufacturers Association	CBEMA
Hewlett-Packard	HP
National Electrical Manufacturers Ass'n	NEMA
GTE Telenet Communications Corp.	Telenet
General Electric	GE
American Telephone and Telegraph Co.	AT&T
Atari, Inc.	Atari
NEMA, Diagnostic Imaging and Therapy System Division	NEMA/DITSD

APPENDIX B

Title 47 of the Code of Federal Regulations, Parts 2 and 15, is amended as follows:

1. The title of Subpart J of Part 2 is amended as follows:

SUBPART J-EQUIPMENT AUTHORIZATION PROCEDURES

2. Section 2.901 is amended as follows:

GENERAL PROVISIONS

Section 2.901 Basis and purpose.

(a) In order to carry out its responsibilities under the Communications Act and the various treaties and international regulations, and in order to promote efficient use of the radio spectrum, the Commission has developed technical standards for radio frequency equipment and parts or components thereof. The technical standards applicable to individual types of equipment are found in that part of the rules governing the service wherein the equipment is to be operated. In addition to the technical standards provided, the rules governing the service may require that such equipment be verified by the manufacturer or importer, or that such equipment receive equipment authorization from the Commission by one of the following procedures: type approval, type acceptance, certification, or telephone equipment registration.

(b) The following sections describe the verification procedure and the procedures to be followed in obtaining type approval, type acceptance or certification from the Commission and the conditions attendant to such a grant.

3. A new Section 2.902 is added to read as follows:

Section 2.902 Verification

(a) Verification is a procedure where the manufacturer makes measurements or takes the necessary steps to insure that the equipment complies with the appropriate technical standards. Submittal of a sample unit or representative data to the Commission demonstrating compliance is not required unless specifically requested by the Commission pursuant to Section 2.957, below.

(b) Verification attaches to all items subsequently marketed by the manufacturer or importer which are identical as defined in Section 2.908 to the sample tested and found acceptable by the manufacturer.

4. Section 2.908 is amended to read as follows:

Section 2.908 Identical defined

As used in this subpart, the term identical means identical within the variation that can be expected to arise as a result of quantity production techniques.

5. The undesignated subheading after Section 2.908 is revised to read as follows:

APPLICATION PROCEDURES: TYPE APPROVAL, TYPE ACCEPTANCE, CERTIFICATION, VERIFICATION

6. A new undesignated heading is added after Section 2.947 and new Sections 2.951-2.957 are added to read as follows:

VERIFICATION

Section 2.951 Cross reference

The provisions of Section 2.901, et seq., shall apply to equipment subject to verification.

Section 2.952 Limitation on verification

(a) Verification signifies that the manufacturer or importer has determined that the equipment has been shown to be capable of compliance with the applicable technical standards if no unauthorized change is made in the equipment and if the equipment is properly maintained and operated. Compliance with these standards shall not be construed to be a finding by the manufacturer or importer with respect to matters not encompassed by the Commission's rules.

(b) Verification of the equipment by the manufacturer or importer is effective until   a termination date is otherwise established by the Commission.

(c) No person shall, in any advertising matter, brochure, etc., use or make reference to a verification in a deceptive or misleading manner or convey the impression that such verification reflects more than a determination by the manufacturer or importer that the device or product has been shown to be capable of compliance with the applicable technical standards of the

(2) A record of the procedures used for production inspection and testing (if tests were performed) to insure the conformance required by Section 2.953. (Statistical production line emission testing is not required).

(b) The records listed in paragraph (a) of this section shall be retained for two years after the manufacture of said equipment item has been permanently discontinued, or until the conclusion of an investigation or a proceeding if the manufacturer or importer is officially notified that an investigation or any other administrative proceeding involving his equipment has been instituted.

Section 2.956 FCC inspection and submission of equipment for testing.

(a) Each manufacturer or importer of equipment subject to verification shall upon receipt of reasonable request submit to the Commission the records required by Section 2.955.

(b) The Commission may require the manufacturer or importer of equipment subject to verification to submit one or more of sample units for measurements at the Commission's Laboratory.

(c) In the event the manufacturer believes that shipment of the sample to the Commission's Laboratory is impractical because of the size or weight of the equipment, or the power requirement or for any other reason, the applicant may submit a written explanation why such shipment is impractical and should not be required.

Section 2.957 Sampling tests of equipment compliance

The Commission will from time to time, request the manufacturer or importer to submit to the FCC Laboratory in Columbia, Maryland, various equipment(s) for which verification has been made, to determine the extent to which subsequently produced units continue to comply with the applicable standards. Shipping costs to the Commission's Laboratory and return shall be borne by the manufacturer or importer.

7. Section 15.4 is amended by deleting paragraph (r) and by adding a new paragraph (r) to read as follows:

Section 15.4 General definitions

* * * * * *

(r) Peripheral Device. A self-contained input/output unit of a system that feeds data into a computer and/or receives data from a computer, including, for example, terminals, printers, Commission's rules.

Section 2.953 Responsibility of manufacturer or importer

(a) In verifying compliance, the manufacturer or importer (in the case of imported equipment) warrants that each unit of equipment marketed under the verification procedure will conform to the unit tested and found acceptable by the manufacturer or importer and that data on file with the manufacturer or importer continues to be representative of the equipment being produced under such verification within the variation that can be expected due to quantity production and testing on a statistical basis.

(b) The importer of equipment subject to verification may upon receiving a written statement from the manufacturer that the equipment complies with the appropriate technical standards rely on the manufacturer or independent testing agency to verify compliance. The test records required by Section 2.955 however should be in the English language and made available to the Commission upon a reasonable request.

(c) In the case of transfer of control of equipment, as in the case of sale or merger of the grantee, the new manufacturer or importer shall bear the responsibility of continued compliance of the equipment.

(d) Equipment verified by the manufacturer or importer shall be reverified if the modification or change adversely affects the emanation characteristics of the modified equipment. The manufacturer or importer continues to bear the responsibility for continued compliance of subsequently produced equipment.

Section 2.954 Identification

The identification of equipment subject to verification shall be consistent with current manufacturer or marketing practices, provided the manufacturer or importer maintains adequate identification records for each unit verified to facilitate positive identification of each equipment marketed.

Section 2.955 Retention of records

(a) For each equipment subject to verification, the manufacturer (or importer) shall maintain the records listed below:

(1) A record of the original design drawings and specifications and all changes that have been made that may affect compliance with the requirements of Section 2.953.

floppy disc devices, other data storage devices, video monitors, keyboards, and other input/output devices that may or may not contain digital circuitry.

8. The introductory paragraph of Section 15.810 is amended as follows and the NOTE directly thereunder is deleted (the remainder of the section is unchanged):

Section 15.810 Class A computing device: radiation limit

Emanations from a Class A computing device, including any network of conductors and appartus connected thereto, shall not exceed the level of field strength specified in the table below. The method for determining compliance with these limits shall be in accordance with the test procedures in Section 15.840.

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9. The introductory paragraph of Section 15.812 is amended as follows and the NOTE directly thereunder deleted (the remainder of the section is unchanged):

Section 15.812 CLASS A COMPUTING DEVICE: CONDUCTION LIMIT

A Class A computing device which is designed to be connected to a low voltage public utility power line shall limit radio frequency voltage conducted back into the power lines to values below the levels specified in the following table when measured pursuant to Section 15.840.

* * * * * *

10. The introductory paragraph of Section 15.830 is amended as follows and the NOTE directly thereunder deleted (the remainder of the section is unchanged):

Section 15.830 Class B computing device: radiation limit

All emanations from a Class B computing device or system, including any network of conductors and apparatus connected thereto, shall not exceed the level of field strengths specified in the table below, when tested pursuant to the procedures for such a device in Section 15.840.

* * * * * *

11. The introductory paragraph of Section 15.832 is amended as follows and the NOTE directly thereunder is deleted (the remainder of the section is unchanged):

Section 15.832 Class B computing device: conduction limit

A Class B computing device that is designed to be connected to a low voltage public utility power line which is intended to feed electrical power to residential dwellings shall limit radio frequency voltage conducted back into the power lines to not more than 250 microvolts over the frequency range 450 to 30,000 kHz, when measured pursuant to Section 15.840.

* * * * * *

12. A new Section 15.840 is added to read as follows:

Section 15.840 Computing Device Test Procedures

Effective July 1, 1981, Computing devices subject to certification shall be tested in accordance with the procedure specified in FCC Methods of Measurements of Radio Noise Emissions from Computing Devices available from the U.S. Department of Commerce, National Technical Information Service (NTIS), Springfield, Virginia 22151. Equipment subject to verification shall be tested in accordance with the above specified procedure to the extent practicable. Tests of computing devices performed by the Commission will follow the above prescribed procedure. Prior to July 1, 1981, computing devices may be tested in accordance with either the above procedure or the interim procedures discussed in the First Report and Order in FCC Docket 20780.

APPENDIX C

FCC MEASUREMENT PROCEDURE 1 (1981)

Office of
Science and
Technology

Federal
Communications
Commission
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FCC METHODS OF MEASUREMENTS OF RADIO NOISE EMISSIONS FROM COMPUTING DEVICES

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1.0 SCOPE

This standard sets forth uniform methods of measurement of radio noise emitted from computing devices defined in Section 15.4 of FCC Rules. The technical standards for computing devices are set forth in Subpart J of Part 15 of FCC Rules (47 CFR 15-J). Methods for the measurement of radiated and powerline conducted radio noise are covered herein. These methods of measurement will be used by the FCC in testing computing systems, computing devices, and units, sub-units, and peripheral devices intended to be used with computing devices. Applicants for certification of Class B computing devices shall employ these methods. Parties required to conduct verification testing of computing systems should take note of these procedures insofar as they apply to testing of such systems so that the tests which they conduct can be expected to provide reasonable assurance that the resulting technical data will correlate with the results of tests conducted in accordance with this standard on such computing systems. Sampling testing of certified or verified computing devices of systems by the FCC will be conducted in accordance with these methods of measurement.

2.0 REFERENCE STANDARD

The following shall form a part of this standard to the extent applicable: American National Standard Specifications for Electromagnetic-Interference and Field Strength Instrumentation, 10 kHz to 10 GHz, ANSI C63.2 (1980).

3.0 DEFINITIONS

The definitions in Parts 2 and 15 of FCC Rules and the following definitions shall apply to use of this standard.

3.1 EQUIPMENT UNDER TEST (EUT)

A representative computing device or system, peripheral etc. being tested or evaluated.

3.2 AMBIENT LEVEL

The magnitude of radiated or conducted signals and noise existing at a specific test location and time.

3.3 EMISSION

Electromagnetic energy produced by a device which is radiated into space or conducted along wires and is capable of being measured.

3.4 GROUND PLANE

A conducting surface used to provide uniform reflection of an impinging electromagnetic wave. Also, the common reference point for electrical potentials.

3.5 LINE-IMPEDANCE STABILIZATION NETWORK (LISN)

A network (sometimes called mains network) inserted in the supply mains lead of the EUT that provides a specified measuring impedance for radio-noise voltage measurement and isolates the EUT and the measuring equipment from the supply mains at radio frequencies.

3.6 RADIO NOISE

Electromgnetic energy in the radio frequency range that may be superimposed upon a wanted signal.

3.7 RADIATED RADIO NOISE

Radio noise radiated into space. Such noise may include both the radiation and induction components of the field.

3.8 CONDUCTED RADIO NOISE

Radio noise propagated from the device back into the public electrical power network via the supply cord.

3.9 RANDOM NOISE

Electromagnetic disturbance (noise) originating in a large number of discrete disturbances with random occurrences in time and amplitude. The term is most frequently applied to the limiting case where the number of transient disturbances per unit time is large, so that the spectral characteristics are the same as those of thermal noise (thermal noise and the shot noise are specified cases of random noise).

3.10 NARROWBAND RADIO NOISE

Radio noise having a spectrum exhibiting one or more sharp peaks, narrow in width compared to the nominal bandwidth of the measuring instrument, and far enough apart in frequency to be resolvable by the instrument.

3.11 BROADBAND RADIO NOISE

Radio noise having a spectrum broad in width as compared to the nominal bandwidth of the measuring instrument, and whose spectral components are sufficiently close together in frequency and uniform that the measuring instrument cannot resolve them.

4.0 GENERAL TEST CONDITIONS

4.1 TEST SITES

An environment is required which assures valid, repeatable measurement results. A measurement is valid to the extent that it is a true representation of the characteristic being measured, and when the same measurement procedure yields repeatable results. For radiated measurements on representative samples of an equipment type, testing is normally conducted in an open field (see 4.1.1). Other alternatives are permitted (see 4.1.1.1 and 4.1.1.2). For equipment which can only be tested in its place of use, and the conditions of 4.1.1.1 cannot be satisfied, then the conditions of 4.1.2 shall apply. A description of the test facility used for testing computing devices subject to certification shall be filed with the Commission, pursuant to Section 15.38 of the FCC Rules (47 CFR 15.38).

NOTE: A rulemaking proceeding in Docket 21371 proposes to replace Section 15.38 with a new section in Part 2 of FCC Rules.The new section will include revised and expanded requirements including a measurement of the site attenuation of an open field test site. The method of making site attenuation measurements is also covered in Docket 21371.

4.1.1 OPEN FIELD TESTS

Measurements of radiated radio noise should be made in an open, flat area characteristic of cleared, level terrain. Such test sites shall be void of buildings, electric lines, fences, trees, etc. and free from underground cables, pipelines, etc. except as required for the measuring equipment and the EUT. (Note: A metal fence or other reflecting object shall be sufficiently far from the site so as not to introduce additional unknown factors). The distance between the device and the measurement antenna can be 3 to 30 meters. If the EUT occupies a volume of less than a meter cube, tests should preferrably be made at a 3 meter distance. The distance from the EUT to the measuring antenna shall be measured from the closest part of the device or system (see 4.7). This distance will, of course, vary to some degree as the EUT is rotated, but if the variation is small compared to the measurement distance, the variation can for all intents and purposes be neglected. In other words, by testing small systems at 3 meters and large systems at between 3 and 30 meters, the variation in test distance due to EUT rotation can be ignored in most instances. Measurements made by the Commission will be performed on an open field test site.

4.1.1.1 TESTS AT LABORATORY, FACTORY, OR OTHER FACILITIES

Compliance with the FCC limits for computing devices shall be based on tests being made in an open field test site, or equivalent, unless measurements are made at the user's premises for a unique installation per Section 4.1.2. Where it can be shown that the results of tests made in a laboratory, factory, anechoic room, dedicated factory site or other facility are correlateable to those made in an open field site, such test results will be considered acceptable. Sufficient tests over the entire frequency range of 30 to 1000 MHz shall be made to demonstrate that the alternative site produces results that correlate with the results of tests made in an open field. In the event that the Commission tests a sample device, measurements will be made in an open field and the results so obtained will determine compliance.

4.1.1.2 TESTING IN A SHIELDED ENCLOSURE

Radiation measurements made in a shielded enclosure are suitable only for determining the frequency profile an EUT; they are not suitable for determining the actual levels of the emissions unless it can be shown that the results of tests made in the enclosure are correlateable to those made in an open field. Conducted radio noise measurements made in a shielded enclosure are acceptable and, in fact, are preferable.

4.1.2 TESTING AT USER'S INSTALLATION (ON-PREMISES TESTING)

Testing is permitted at the end user's premises, where the conditions of 4.1.1 or 4.1.1.1 cannot be satisfied. In this case, both the equipment and its location are considered the EUT. The radiated emission results are unique to the installation site because site containment properties affect the measurement. The conducted emanation results also may be unique to the installation. However, where testing of a given system has been accomplished at three or more representative locations, the results can be considered representative of all sites for purposes of determining compliance with emission requirements. See 4.7 and 6.3.

4.1.3 INDIVIDUAL EQUIPMENT TEST REQUIREMENTS

In some cases, it may be necessary to develop a set of explicit requirements specifying the test conditions, EUT operation, etc. to be used in testing a specific EUT or specific class of EUT's for radio noise emissions. Such requirements shall be documented in the report of measurements for the EUT and may be used in determining compliance with FCC limits. It would be advisable to obtain concurrence from the Commission that the special requirements and procedures to be followed are satisfactory before actually performing the measurement.

4.2 MEASUREMENT INSTRUMENTATION

Measurements of radiated and conducted radio noise shall be made with a radio noise meter conforming to the American National Standard Specifications for Electromagnetic Interference and Field Strength Instrumentation 10 kHz to 10 GHz, C63.2 (1980). Alternatively, a spectrum analyzer may be used as the measuring instrument, provided that it is used, when necessary, with appropriate accessories to provide sufficient sensitivity and overload protection to insure accurate, repeatable measurements of all emissions over the specified frequency range. Other instruments may be used for certain restricted and specialized measurements when data so measured is correlated to that achieved with C63.2 instrumentation.

Note: Accessories needed would depend upon the measurement situation and could include preamplifiers for sensitivity improvement, filters and/or attenuators for overload protection, and additional quasi-peak detection circuitry. Overload is defined as harmonic distortion, intermodulation, or gain compression of spectrum analyzer input signals. Precaution may have to be taken to insure that the spectrum analyzer operates linearly before taking final measurements. Consult user's manual for instructions and guidance. Application notes on the use of spectrum analyzers and other instruments are also available from several manufacturers.

4.2.1 MEASURING INSTRUMENT CALIBRATION

The calibration of the measuring instrument, including any accessories that may affect such calibration, shall be checked frequently enough to assure its accuracy. Adjustments shall be made and correction factors applied in accordance with instructions contained in the manual for the measuring instrument.

4.2.2 DETECTOR FUNCTION SELECTION AND BANDWIDTH

During radiated emission testing, radio noise meters, or spectrum analyzers which include weighting circuits, shall have the detector function set to the CISPR quasi-peak function. The 6 dB bandwidth of the measuring instrument shall not be less than 100 kHz for field strength measurements over the frequency range of 30 to 1000 MHz. During conducted voltage testing, radio noise measuring instruments shall have the detector function set to the CISPR quasi-peak function. The 6 dB bandwidth of the necessary measuring instrument shall not be less than 9 kHz over the frequency range 450 kHz to 30 MHz. Post detector video filters, if used, shall be wide enough not to affect the peak detector reading. Alternatively, field strength meters and spectrum analyzers without CISPR weighting circuits may be employed, provided measurements are made on the peak basis, and recorded as observed (without any presumed correction for the difference between CISPR quasi-peak and peak detector function).

Note: 1. The above specified bandwidths have tolerances as prescribed in ANSI standard C63.2-1980.

2. If bandwidths greater than those expressed in 4.2.2 are used, higher readings may result for EUT's with broadband emanations.

3. Data taken with measuring instrumentation employing logarithmic amplifiers when using the average function will represent the average of the logarithm of the voltage level. If the emanation observed is pulsed, broadband observed values will be materially lower than the true average of voltage. Instrument overload is likely to occur with linear IF systems if the emission pulse duty cycle is less than that for which the measuring instrumentation is rated. Data correction for spectrum analyzer observations should include corrections for pulse desensitization factor; with this correction applied to peak indications, if the duty cycle is known or can be measured, average values of emanations can be calculated.

4. For line conducted tests, if the equipment exhibits emissions which exceed the limit under the above specified conditions the following option may be exercised. The measurements may be made in the average mode with a 9 kHz minimum bandwidth. If the signal level in average mode is significantly less than in peak or quasi-peak mode, the emission is considered broadband and the quasi-peak value may be reduced by 13 dB for comparison to the limit.

4.2.3 UNITS OF MEASUREMENT

Measurements of radiated interference shall be reported in terms of microvolts per meter, or dB (uV/m) at a specified distance. The indicated readings on the radio noise meter or spectrum analyzer shall be converted to microvolts per meter, or dB (uV/m) by use of appropriate conversion factors. Measurements of conducted interference shall be reported in terms of microvolts or dB (uV). Measured data may be presented in tabular or graphical form. Alternatively, recorder charts from automatic measuring equipment or photographs of spectrum analyzer displays may be used, providing that the calibration levels, in terms of uV/m or dB (uV/m) are shown on such charts or photograhs.

4.2.4 ANTENNAS

A calibrated, tuned half-wave dipole antenna is preferred for measuring the level of radiated emissions. Other linearly polarized antennas are acceptable provided the results obtained with such antennas are correlateable to levels obtained with a tuned dipole. The antenna shall be capable of measuring both horizontal and vertical polarizations. For measurement distances of up to 10 meters the height of the antenna for horizontal polarization shall be capable of being varied from 1 to 4 meters. At measurement distances of 10 meters and beyond, for horizontal polarization the antenna shall be capable of being varied from 2 to 6 meters. In the case of vertical polarization of the antenna, the maximum heights stated for horizontal polarization apply (as measured to the center of the antenna); however, the minimum height should be increased so that the lowest point of the bottom end of the dipole (or other antenna), at any frequency, clears the site ground surface by approximately 25 cm. Over the frequency range of 30 to 1000 MHz, the Commission will use tuned half wave dipole antenna for compliance testing.

4.2.5 PRELIMINARY TESTING AND MONITORING

Preliminary radiated measurements should be made indoors, preferably in an enclosure, at a closer distance than specified for compliance, to determine the emission characteristics of the EUT. It is suggested that where a radio noise meter is used for this spectrum search that either a headset or loudspeaker be connected as an aid in detecting ambient signals and finding frequencies of significant emission from the EUT. Precautions shall be taken to ascertain that the use of a headset or loudspeaker does not affect the radio noise meter indication during testing. The arrangement of EUT units and cabling should be varied as necessary (within the scope of arrangements likely to be encountered in actual use) to ascertain to what extent this affects the emanations, in frequency, strength, and directivity of radiation. Adequate notes should be kept, both as to EUT arrangement and the frequency and strength of significant emissions, to assure that the final tests made on the test site will represent the worst-case emanation potential of the EUT.

4.3 FREQUENCY RANGE TO BE SCANNED

For radiation measurements, the frequency range from 30 MHz to 1000 MHz shall be searched. For conducted measurements, the frequency range from 450 kHz to 30 MHz shall be searched. The six highest emissions relative to the appropriate limit shall be measured and reported. To facilitate testing with a radio noise meter, the frequency range covered in the particular test should be scanned while monitoring with headset or loudspeaker. If any indicated peaks appear while scanning, readings shall be taken at the frequencies where they occur. The scan rate shall be such that noise signals above radio noise meter sensitivity threshold are not omitted from detection.

Note: Automatic scan techniques are acceptable but the maximum scan speed is limited by the response time of the measuring system and (where applicable) the repetition rate of the radio noise to be measured.

4.4 DATA REPORTING FORMAT

The measurement results expressed in accordance with 4.2.3 and specific limits where applicable, shall be presented in tabular or graphical form, or alternatively as recorder charts or photographs of spectrum analyzer display, showing the level vs. frequency. Since alternate test methods are provided, test data must identify the methods used. Instrumentation, instrument attenuator and bandwidth settings, detector function, EUT arrangements, a sample calculation with all conversion factors and all other pertinent details shall be included along with the measurement results.

Note: In the case of devices required to be certificated, refer also to Part 2 (Sections 2.909, 2.925, 2.926, 2.1033) and Part 15 (Sections 15.38, 15.44, 15.45, 15.46, and 15.79) for general provisions applicable to all applications for certification.

4.5 CONFIGURATION OF EQUIPMENT UNDER TEST (EUT)

It is recommended that all multi-unit systems be tested first as a basic system, consisting of the system controller plus one peripheral of each type proposed for use with that controller. Additional peripherals may then be tested with the basic system as a host system or with a simulator or exerciser. In the latter case, the simulator or exerciser should first be tested to assure that its shielding, etc. are adequate to assure that its contribution to the emanations of the EUT/simulator combination are insignificant. If the computing device is designed to be connected to multiple peripherals all of which are identical, it is only necessary to perform tests with one of that type peripheral connected.

4.5.1 TEST CONDITIONS FOR EUT

The equipment under test (EUT) shall be configured and operated in a manner which tends to maximize its emission characteristics in a typical application. Power and signal distribution, grounding, interconnecting cabling and physical placement of equipment or equipments of a test system shall simulate the typical application and usage in so far as practicable. The EUT shall be furnished with rated (nominal) voltage as specified in the individual-equipment power requirements. The power supplied to the EUT may need to be filtered to meet the requirements of 4.6.1.

4.5.2 OPERATING CONDITIONS

The EUT shall be operated at the specified load conditions (mechanical and/or electrical) for which it is designed. Loads may be actual or simulated as described in the individual equipment requirements.

4.5.3 CONDITIONING OF THE EUT

The EUT shall be operated for a sufficient period of time to approximate normal operating conditions.

4.5.4 INTERFACING UNITS AND SIMULATORS

In case the EUT is required to interact functionally with other units, either the actual interfacing units or simulators may be used to provide representative operating conditions, provided the effects of the simulator can be isolated or identified. It is important that any simulator used in lieu of an actual interfacing unit properly represent the electrical, and in some cases the mechanical, characteristics of the interfacing units, especially concerning RF signals and impedances.

If the EUT is a peripheral device being separately measured for compliance to a limit on radio noise, the EUT must be tested with at least one host computer or simulator in a typical configuration. It is not necessary to test the EUT with all possible host computers or in all potential configurations.

Interconnecting cables should be of the type and length specified in the individual equipment requirements. If the length may vary, tests should be made with two sets of cables, one with all cables of the shortest length proposed, the other with all cables of the longest length for which the EUT is rated. Excess length of cables should be bundled at the approximate center of the cable, with the bundle 30 to 40 cm in length.

4.5.5 EUT GROUNDING

The EUT shall be grounded in accordance with the manufacturer's requirements and conditions of intended use. If the EUT is operated without a ground connection, it shall be tested ungrounded. When the EUT is furnished with a grounded terminal or internally-grounded lead, and when this terminal or lead is used in actual installation conditions, the ground lead or connection shall be connected to a ground plane (or facility for earth ground). simulating actual installation conditions. Any internally-grounded lead included in the plug end of the line cord of the EUT shall be connected to ground through the utility power service (see also 5.1 and 5.4).

4.6 TEST ENVIRONMENT

The environment at the test site should satisfy the following conditions:

4.6.1 AMBIENT RADIO NOISE AND SIGNALS

It is desirable that the conducted and radiated ambient radio noise and signal levels, measured at the test site with the test sample de-energized, be at least 6 dB below the allowable limit of the applicable specification or standard. However, in the event that the measuring levels of the ambient plus EUT radio noise emissions are not above the applicable limit, the EUT shall be considered to be in accordance with the limit.

If the ambient field or the power line ambient level at some frequencies within the specified measurement ranges exceeds the applicable specification limit(s), other test methods may be used to show EUT compliance. The following would constitute some of the acceptable alternatives:

- Perform measurements at closer than the specified distances and extrapolate the result(s) to the specified limit distance using an inverse distance linear attenuation factor.

- Perform measurements of critical frequency bands during hours when broadcast stations may be off the air and industrial ambients are lower.

- Resort to measurement in an enclosure or anechoic room (see 4.1.1.1 and 4.1.1.2 for conditions of use). Measurements made in a shielded (metal) enclosure are normally not acceptable for the purpose of determining compliance. However, by making observations in such enclosure to observe the relative levels of the emissions affected by ambient interference and also other EUT emissions in the same general frequency range, these observations taken together with measurements on the test site (at reduced bandwidth where necessary) can enable reasonably accurate determination of the strength of the EUT emissions affected by ambient interference.

- Insert line filters between the power source and the LISN or between the power source and the EUT as appropriate for the particular measurement.

Note: In orienting the axis of a test site, it is desirable to consider the directions of strong ambient signals, so that the orientation of the receiving antenna on the site discriminates against such signals insofar as possible.

4.6.2 TEMPERATURE

The ambient temperature of the testing location should preferably be within the range of 10 to 40 degrees C. (50 to 104 degrees F) unless the individual equipment requirements specify testing over a wider temperature range. Measurements made in temperatures outside these limits may be accepted, provided the EUT, radio noise meters, all indicating devices, and equipment are at the testing location sufficiently long that their temperature become stabilized with respect to the temperature of the testing location. Evidence shall be given so that the calibrations of the measuring instruments used are accurate at the temperatures at which they are used.

4.7 ARRANGEMENTS OF EUT (ON TEST SITE)

The EUT shall be arranged to the extent practical in a manner which simulates actual use, with the several units placed as nearly as possible in the worst-case setup found in preliminary tests per paragraph 4.2.5. An EUT which is normally operated on a table shall be placed on a non-conducting table having a height of 1 meter above test site ground level. For ease of testing, the table may be placed on a rotatable platform, in which case the total height of the table plus the platform shall be approximately 1 meter above test site ground level. If the platform is elevated, it should be non-conducting to the maximum extent practicable. In the event that all the units or peripherals of an EUT system will not fit on the table, one or more of these may be placed on non-conductive shelves below the table top, using the minimum spacing below the top for their placement. In selecting units for placement on the shelf, first preference should be given to those normally not requiring frequent attention.

For an EUT normally placed on the floor, the equipment should, if practicable, be placed on a rotatable platform. If the platform is elevated it should be non-conducting to the maximum extent practicable and have a height of not more than 0.5 meters above ground level.

The EUT shall be located in the center of the platform. If the EUT consists of two or more units, these shall be arranged around the center of the platform consistent with actual use, placed as nearly as possible in the worst-case setup found in preliminary test per paragraph 4.2.5.

Power and signal distribution, grounding, interconnecting cables and physical placement of the units should simulate as nearly as possible typical application and use. Starting with the worst-case setup found in paragraph 4.2.5, the arrangement of units and interconnectng cables should be varied (within the range of positions likely to occur in actual use) to maximize the strength of the strongest emission of those present (using data from the paragraph 4.2.5 tests as guidance). A sufficient number of arrangements shall be investigated to insure that the maximum radiation is measured.

The horizontal distance between the measuring set antenna nd the EUT shall be measured from the closest point of the device or system, as determined by the boundary defined by an imaginary straight line periphery describing a simple geometric configuration enclosing the EUT system. (See Figure 1) All intra-system cables and connecting devices shall be included within this boundary. Excess length of cables shall be bundled at the approximate center of each cable by folding back and forth so as to form a bundle not exceeding 30 cm to 40 cm in length. For a Class B computing device, radiation measurements may be made at any distance between 3 and 10 meters provided the results are extrapolated to 3 meters using the inverse distance linear relationship; for a Class A computing device radiation measurements may be made at any distance between 3 and 30 meters and the data extrapolated to 30 meters using the inverse distance linear relationship. (See 6.2)

For an EUT located at the user's premises, measurements should be made at the appropriate limit distance measured horizontally from the boundary described by an imaginary straight line periphery describing a simple geometric boundary that encompasses all EUT units. All EUT units and connecting cabling should be within the boundary. Where measurements at the greater limit distance (e.g., 30 meters) are impractical, measurements may be made at lesser distance (e.g., 3 or 10 meters) and extrapolated to 30 meters according to the inverse distance linear relationship.

4.8 GROUND PLANE

A ground screen is desirable, but not mandatory. It is pointed out, however, that open field sites are likely to need a ground screen to meet the quality standards contemplated in FCC Docket 21371 to be set forth in Part 2, Subpart J of the FCC Rules, when any of the following conditions exist at the site: the terrain is discontinuous, the terrain is subject to extreme seasonal variations in ground conductivity; there are unburied power or control cables; the site is located on pavement.

4.8.1 TESTING AT USER'S INSTALLATION (ON-PREMISE TESTING)

A ground plane need not be installed for testing at a user's installation unless it is to be a permanent part of the installation. If a ground plane is used, it shall be electrically bonded to the utility ground as specified in 4.8.

5.0 CONDUCTED POWERLINE MEASUREMENTS

Unless otherwise specified, measurements shall be made to determine the line-to -ground radio noise voltage which is conducted from the EUT power-input terminals that are directly connected to a public power network. The measurements are to be made with the EUT connected to such network thru a nominal, standardized RF impedance, which is to be provided by a line-impedance stabilization network. A network must be inserted in series with each current-carrying conductor in the EUT power cord.

> NOTE: It is recommended that conducted powerline measurements be made before measurements of radiated emissions, because this procedure is carried on indoors, requires rather little time as compared to radiation measurements, and can give some assurance that the shielding of the EUT is reasonably effective (at least at the lower frequencies).

5.1 CONDUCTED POWERLINE TEST CONFIGURATIONS

The EUT shall be placed at least 40 centimeters from an earth grounded conducting surface approximately 2 meters square unless it is floor standing and shall be kept at least 80 centimeters from any other earthed conducting surface. If the measurement is made in a shielded enclosure, the distance of 40 centimeters may be referred to one of the walls of the enclosure.

If the EUT is supplied without a flexible power lead, it shall be placed at a distance of 80 centimeters from the LISN's (or mains outlet where LISN's cannot be used) and connected thereto by a lead of length not greater than 1 meter.

If the EUT is supplied with a flexible lead, the voltage shall be measured at the plug end of the lead. The length of the lead in excess of the 80 centimeters separating the EUT from the LISN's (or mains outlet where LISN's cannot be used) shall be folded back and forth so as to form a bundle not exceeding 30 to 40 centimeters in length.

If the EUT is normally operated in the hand, measurements shall be made as if it is normally operated while placed on a table or desk. Measurements of power line conducted emanations are not required for devices capable of being operated only from internal batteries. If the EUT is fitted with a connection for operation directly or via separate transformer or power supply from public utility lines, measurements of power line conducted emanations shall be made.

When computing devices or their peripherals have their own provision for connection to a power line, line conducted tests must be performed separately for each device.

5.2 LINE PROBE

A line probe may be used for voltage measurements under certain conditions (see 5.6). If an appropriate LISN which satisfies the impedance requirements of Figure 2, having the current capacity of the EUT is not commercially available, the method shown in Figure 4 may be used. The measurements should be made between each current-carrying conductor in the supply mains and the ground conductor with a blocking capacitor C and a resistor such that the total resistance between line and ground is 1500 ohms. Since the line probe attenuates the radio noise voltage, appropriate calibration factors must be added to the measured values. Measurement results with the appropriate LISN shall take precedence over the method shown in Figure 4.

5.3 LINE-IMPEDANCE STABILIZATION NETWORK

A line-impedance stabilization network (LISN) having an impedance characteristic within the limits shown in Figure 2 is required for conducted radio noise measurements. Figure 3 shows a network which will provide the specified impedance over the frequency range 0.45-30 MHz. A coaxial-type connector shall be provided for connection of the measuring instrumentation by means of a 50-ohm terminating resistance across the 1000-ohm resistor. Provisions shall be made for electrically bonding the LISN enclosure to the ground plane used (see 4.8). If a direct bond is not possible, for instance with concrete floors, a metal sheet approximately 2 meters square shall be placed under the LISN and electrically bonded to the LISN by a short low impedance connection.

Note: LISN's designed to comply with the impedance characteristic of Figure 2 are not yet readily available on the market. As an interim measure, 5 microhenry LISN's may be used, provided that the readings obtained using these networks are increased by adding a correction to obtain a value equivalent to that which would have resulted had a 50 microhenry network been used in the measurement. This correction varies from +10 dB at 450 kHz to 0 dB at 3 MHz; values for frequencies between these limits may be obtained by reference to Figure 5. No correction is required above 3 MHz. This correction is based upon the relative impedance values of the 50 and 5 microhenry LISN networks in the range 450 kHz-30 MHz, and a presumption that the source of the EUT power conductors in this range is low as compared to that of the networks.

5.4 GROUNDING

The LISN housing, measuring instrumentation case, ground plane, etc., shall be electrically bonded together in such a manner that they are at the same RF potential.

5.5 MEASUREMENT PROCEDURE

Measurements of powerline conducted radio noise shall be expressed as the voltage developed across the 50-ohm port terminated by a 50-ohm measuring instrument. All voltage measurements shall be made at the plug end of the EUT power cord, e.g., by the use of mating plugs and receptacles on the EUT and LISN.

5.5.1 EUT POWER LEADS

All EUT input power leads, except ground leads, shall individually be connected through LISN's to the input power source. All unused 50-ohm connectors of the LISN's shall be resistively terminated in 50-ohms when not connected to the measuring instrument.

5.5.2 SHIELDED POWER LEADS

Equipment normally used with unshielded power leads shall be connected to the LISN and tested with unshielded leads. If the EUT is normally operated with shielded or armored leads, the tests shall be made using such leads.

5.6 CONDUCTED EMISSION TESTS AT USER'S INSTALLATION (ON-PREMISES TESTING)

Testing for powerline conducted radio-noise is permitted at the user's installation site, provided that no disturbance to the normal EUT installation exists, except to make provisions for connection of the 1500-ohm line probe specified in 5.2 and Figure 4. Special precautions must be taken to establish a reference ground for the measurements. No LISN shall be used. The measurements are dependent on the impedance presented by the supply mains and may vary with time and location due to variations in the supply-mains impedance. (It may be necessary to perform repeated measurements over a suitable period of time to determine the variation in measured values. The time period should be sufficient to cover all significant variations due to operating conditions at the installation.) Such measurement results should be regarded as unique to that EUT and installation environment.

6.0 RADIATED-EMISSION MEASUREMENTS

Measurements of radiated radio-noise shall be made using the measuring instrumentation and antennae specified in 4.2 and 4.2.4, respectively. Radiation from the EUT including radiation from all signal and power cabling shall be measured. Consistent with Section 4, above, the EUT shall be set up and operated in a manner representative of actual use.

6.1 DETERMINATION OF TEST RADIAL

Radiated emission magnitudes shall be obtained in the azimuthal direction of maximum field strength for each predominate emission.

It is preferable to rotate the EUT to determine the direction of maximum field strength. A turntable arrangement may be used for convenience.

For large, heavy, and stationary electric equipment not readily rotated, the measuring instrument and test antenna may be moved around the EUT at as many points as are necessary to determine the direction of maximum field strength for each predominate emission. Parties making measurements on test sites where the EUT is not rotated should understand that the minimum clearances for a test site with rotatable platform are not applicable; instead, the minimum clearance distance for a test site without a platform is changed to a circular area centered on the EUT location and having a diameter of 3 times the maximum distance between the measuring set antenna and closest point of the EUT.

Whether the EUT is to be tested on a test site with a turntable or is to be left fixed with the measurement antenna moved around it, it is suggested that preliminary tests be made, preferrably indoors rather than on the test site, to determine the system spectrum signature, the strengths of the stronger emissions, and the directions in which these emerge from the system. During this testing, EUT arrangement should be varied within the scope of expected usage to maximize radiation. As provided in paragraph 4.5.3, if lengths of interconnecting cables may vary, tests should be made with one set each of the shortest and longest cables expected to be used, with excess cable length bundled. Using this experimental data as a guide for EUT arrangement, measurements then may be made on the test site. Where the EUT is not rotated on the site, measurements should be made of the strength of each of the emissions noted in the preliminary tests in the azimuthal direction determined in those tests.

6.2 RADIATED RADIO NOISE TESTS

Radiated radio noise measurements shall be made at one of the test sites described in 4.1, above. An EUT subject to a radiated limit at 3 meters, shall be measured at a distance of 3 meters, unless impractical because of size of the equipment, location, etc., in which case measurements may be made at a further distance up to 30 meters and the results extrapolated inwards utilizing an inverse distance extrapolation factor (i.e., 20 dB/decade). Equipment subject to a limit at 30 meters may be measured at a distance of from 3 to 30 meters provided that the results are extrapolated to equivalent signal at 30 meters utilizing an inverse distance extrapolation factor (20 dB/decade). At test distances between 3 meters and 10 meters the antenna shall be varied in height between 1 meter and 4 meters above ground, to determine the maximum level of emissions within this range. Beyond 10 meters, to find the maximum signal level the antenna height shall be varied between 2 and 6 meters above ground. Both horizontal and vertical orientation of the search antenna shall be employed and maximum values reported. For vertical polarization the bottom end of the dipole shall be kept at least 25 cm above site ground per paragraph 4.2.4.

At sites other than open field, it is permissible to replace continuous variation of antenna height with setting the antenna at one or more fixed heights, provided that it can be shown that equivalent results are obtained.

A typical test configuration for open-field and alternative sites is shown in Figure 1. The LISN, installed for the powerline conducted radio-noise measurements, may be left in place for radiated emission tests.

6.2.1 ELECTROMAGNETIC FIELD: 30 MHz to 1 GHz

Any equipment or device to which it is applicable shall be measured for radiated emissions from all units, cables, power lines and interconnecting wiring.

Antenna position in azimuth shall be varied during the measurement in order to determine maximum field strength. Measurement shall be made at the azimuth such that the maximum radiation levels will be detected.

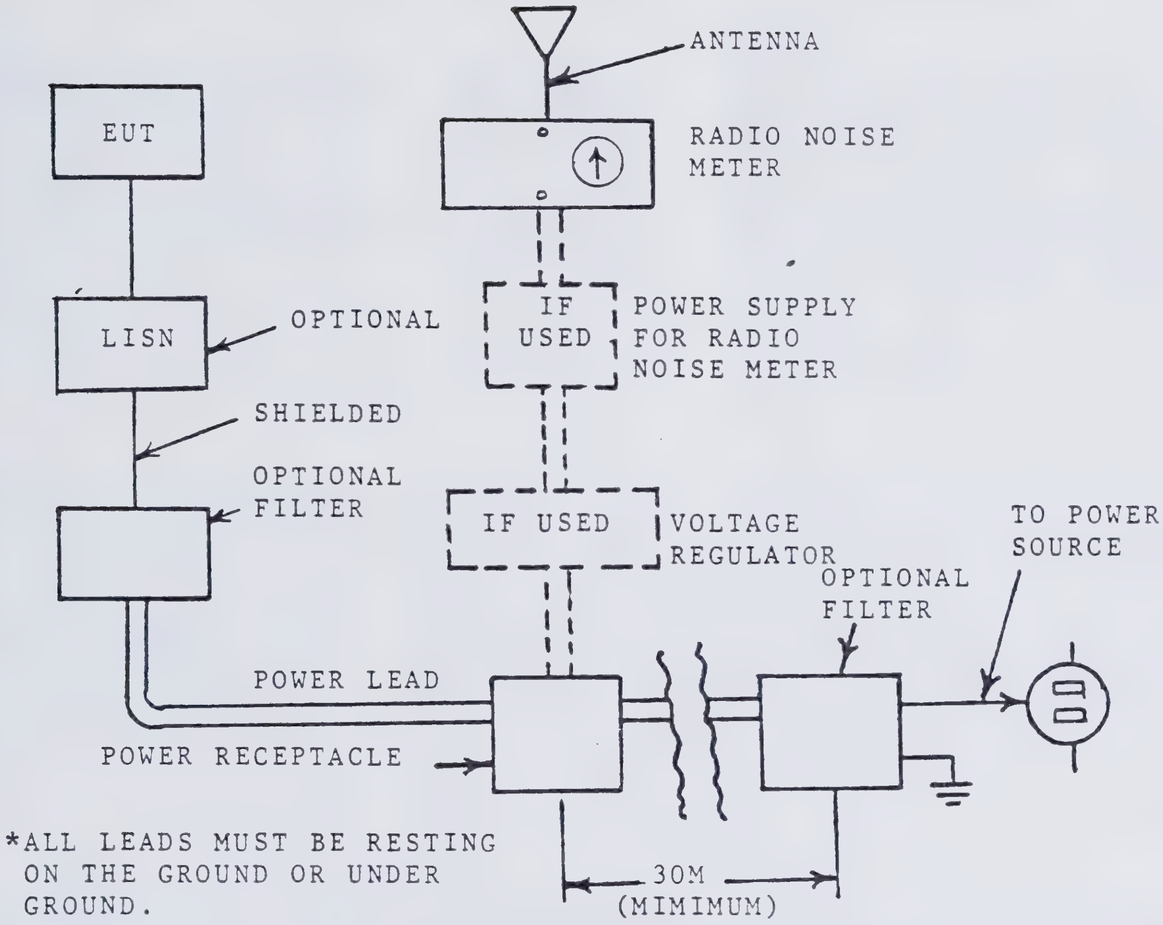
The antenna(s) specified in 4.2.2, above, preferably shall be positioned at the specified distance from the EUT for the duration of this test. Other test distances may be used and data extrapolated to specified distance per paragraph 6.2. Tests shall be made in both the horizontal and vertical planes of polarization.

The area of maximum radiation from the EUT may be initially determined by scanning the power leads and the equipment using the radio noise meter in conjunction with a short electric field antenna at a closer distance.

For record keeping purposes only the maximum emanations observed during the tests need be recorded and maintained in the permanent record file.

6.3 RADIATED EMISSION TESTS AT USER'S INSTALLATION (ON-PREMISES TESTING)

Testing of the installed EUT may be performed at the end-user's installation with the results generally regarded as unique to the EUT and installation environment. However, where testing has been accomplished at three or more representative locations, the results can be considered representative of all sites for purposes of determining compliance with emanation limits. If no detailed instructions are given in the individual equipment requirements, measurements shall be made to locate the radial of maximum emission at a distance 30 meters from the equipment being tested. Where measurements at the 30 meter distance from the EUT are impractical, measurements may be made at lesser distances and extrapolated to the 30 meter distance from the EUT. A LISN shall not be used for testing of the user's installation in order that the measured radio noise voltage be representative of the specific site. Preliminary measurements of EUT spectrum signature directions of radiation may be made per paragraph 6.1.



*ALL LEADS MUST BE RESTING ON THE GROUND OR UNDER GROUND.

FIGURE 1-SUGGESTED LAYOUT FOR OPEN-FIELD TESTS

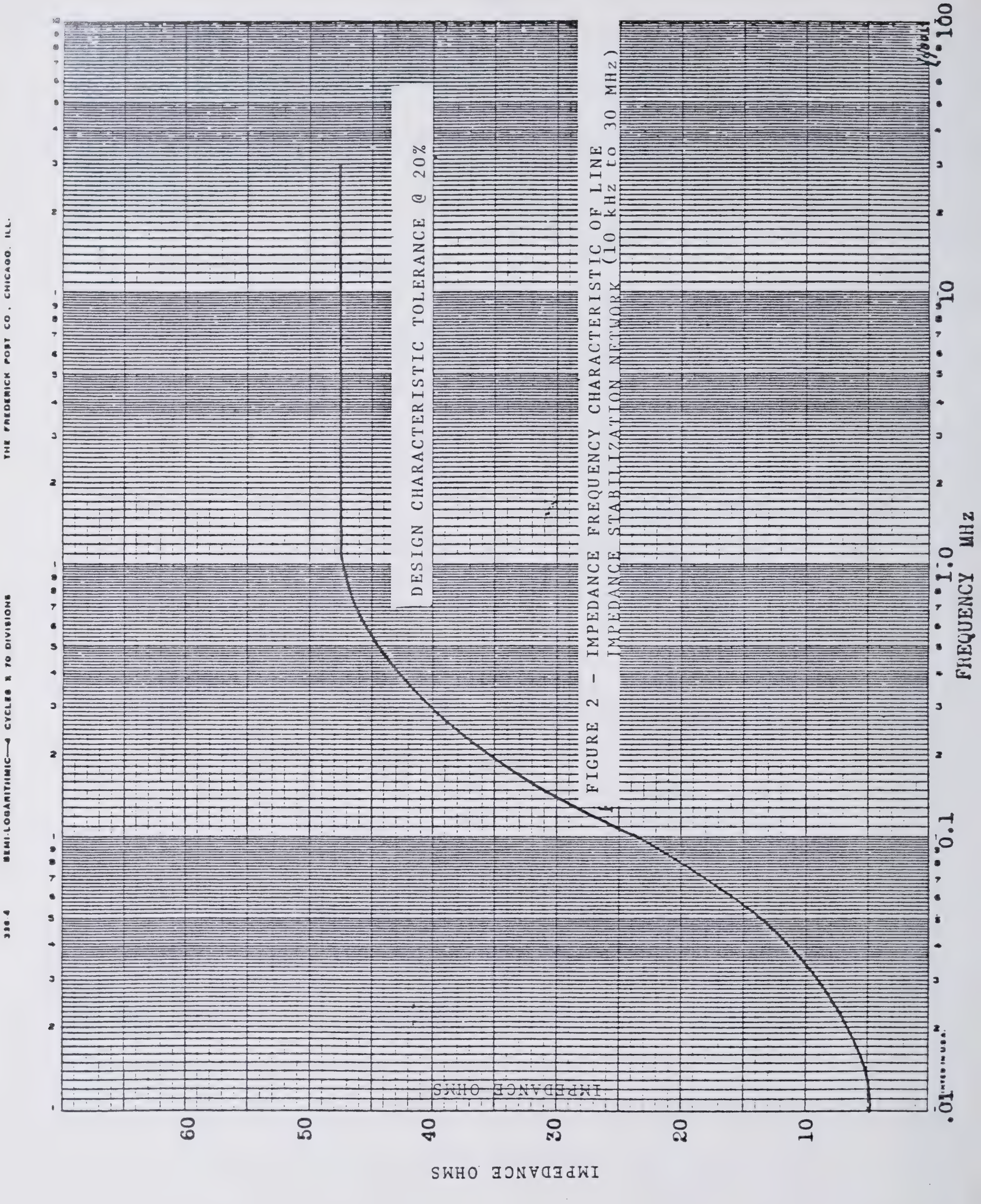


FIGURE 2 - IMPEDANCE FREQUENCY CHARACTERISTIC OF LINE IMPEDANCE STABILIZATION NETWORK (10 kHz to 30 MHz)

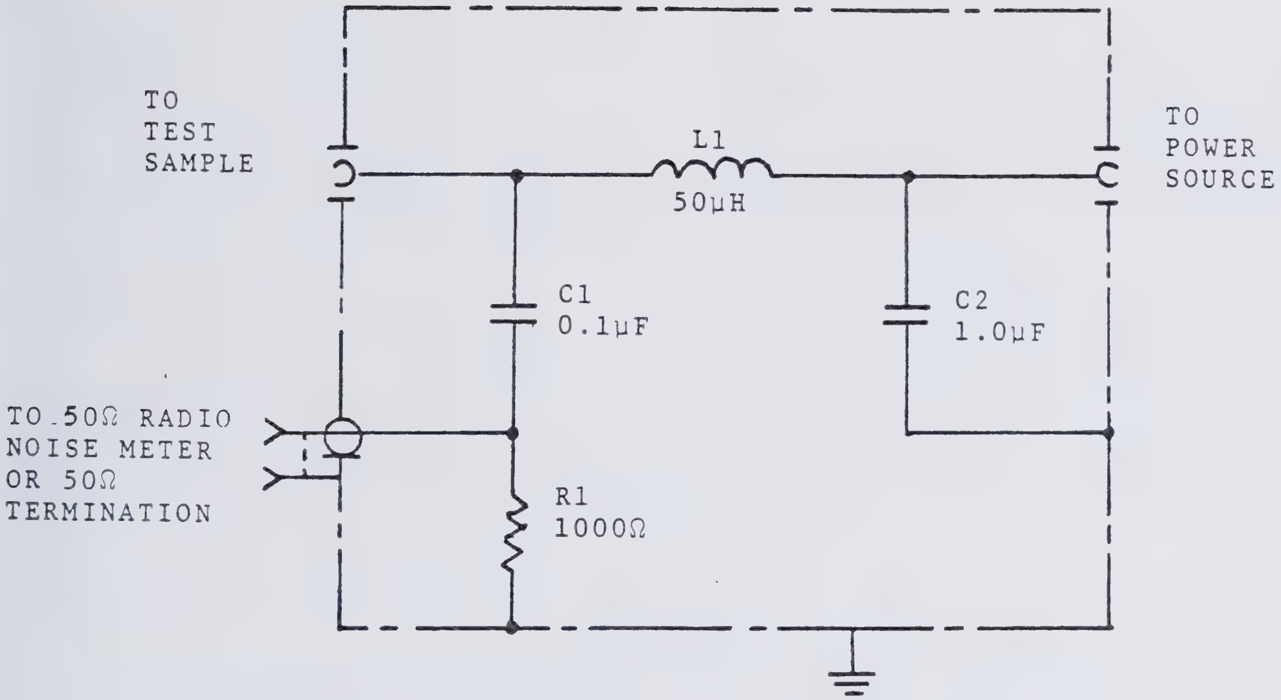


FIGURE 3-CIRCUIT DIAGRAM OF LISN TO PROVIDE IMPEDANCE OF FIGURE 3 FOR THE 0.45-30 MHz FREQUENCY RANGE

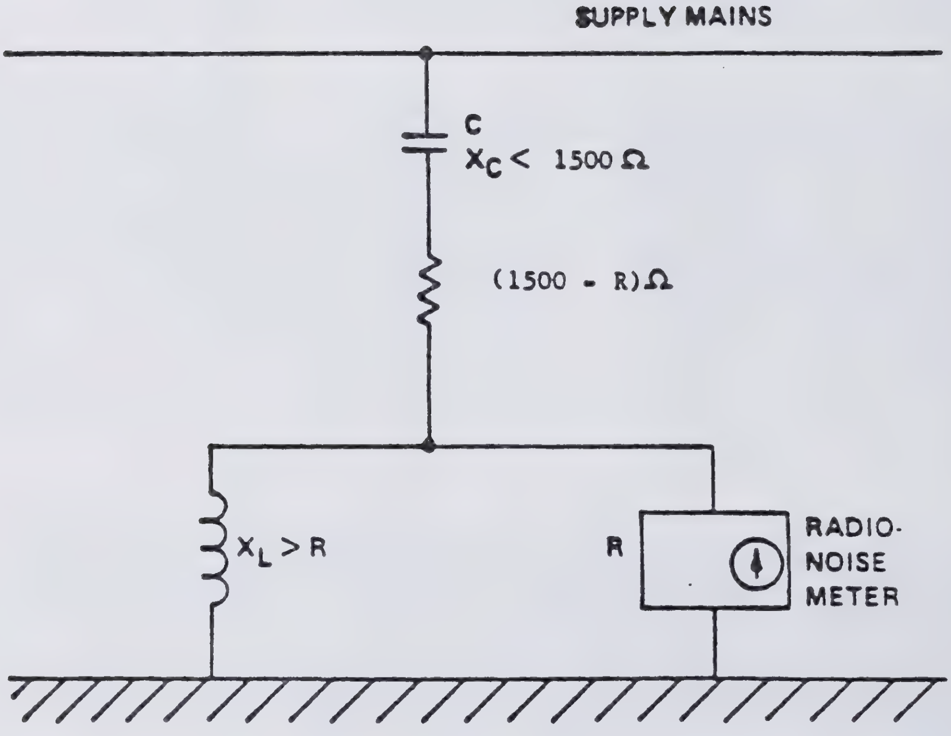


FIGURE 4 LINE PROBE FOR TESTS AT USER'S INSTALLATION

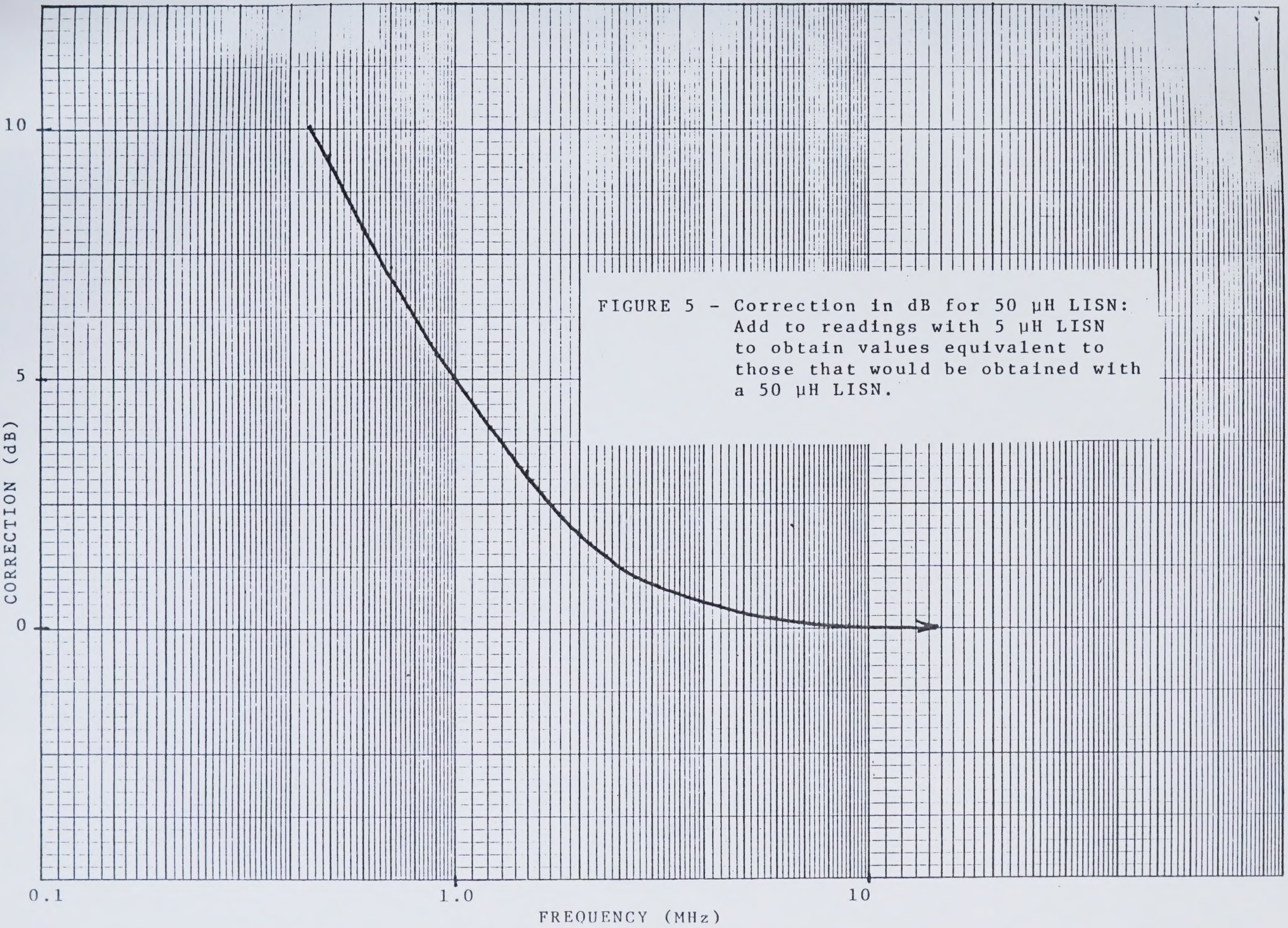


FIGURE 5 - Correction in dB for 50 μH LISN: Add to readings with 5 μH LISN to obtain values equivalent to those that would be obtained with a 50 μH LISN.